TABLE 2-14. ISSUE 11 – WILD AND SCENIC RIVERS							
Alternatives/Units of Comparison	**A**	**B**	**D**	**E**	**F**	**G**	**I**
Wild and Scenic Rivers	**Miles**						
Miles of Rivers Currently Designated	57.0	57.0	57.0	57.0	57.0	57.0	57.0
Miles of Rivers Eligible	62.1	62.1	62.1	62.1	62.1	62.1	62.1
Prescriptions Allocated to Eligible River Corridors	1B, 2B1, 2B2, 2B3, 4D, 5C,10B,12A	1B, 2B1, 2B2, 2B3, 4D, 5C	1B, 2B2, 2B3, 4D, 5C, 10B	1B, 2B1, 2B2, 2B3, 4D, 5C, 12A	1B, 4D, 4F, 5C, 7E1, 8A1, 10B, 11, 12A	1B, 2B1, 4F, 6B, 6D,	1B, 4D, 4F, 5C, 7A, 7E2, 8A1, 9G2, 10B

Issue 12 - Access and Road Management

System roads are the primary means of national forest access; however, they are also a source of many concerns. These concerns predominantly center on the environmental effects of roads (which will be addressed in other issues, such as riparian, threatened, and endangered species, etc.).

Some people would like to see the motorized access to the national forests increased, especially during hunting seasons for big game, for other recreational uses, or to meet forest management needs. Other people, however, are concerned that road construction would be limited and some existing roads obliterated. Other comments were made that new roads should not be constructed for the purposes of logging or for OHV use. The amount of motorized access would need to be balanced with wildlife habitat needs, the need to provide both motorized and non-motorized recreational opportunities, the need to protect the soil and water resources, and the need to have management access.

The revised LMP would need to identify what, if any, are the appropriate road density standards and seasonal restrictions needed to meet the desired conditions established in the LMP.

The following table displays differences in access and road management across alternatives on the Sumter National Forest.

In addressing this issue, management activities would strive to accomplish:

- Provide a transportation system that supplies and improves access for all forest road users within the capabilities of the land.
- Provide a minimum transportation system that supplies safe and efficient access for forest users while protecting forest resources.
- Provide better quality access by upgrading highly used forest roads; and any roads that are needed but are adversely affecting surrounding resource values and conditions.

Table 2-15 shows the comparison of Issue 12 by alternative.

TABLE 2-15. ISSUE 12 – ACCESS AND ROAD MANAGEMENT

Alternative/Units of Comparison	A	B	D	E	F	G	I
Transportation System	Acres in Thousands						
Construction and Reconstruction Prohibited	15.1	14.9	9.6	13.8	8.4	13.6	8.1
Density of Open Roads and Motorized Trails Should Decrease Over Time	18.2	143.0	6.5	251.0	28.1	225.3	73.3
Density of Open Roads and Motorized Trails Should Remain Near Existing Levels	324.3	203.2	345.0	92.8	323.8	122.2	279.7
Density of Open Roads and Motorized Trails May Increase Over Time	3.5	0	0	3.5	7.2	0	0

Issue 13 – Chattooga River Watershed

Issues relate to managing the Chattooga Watershed for the desired social and ecological benefits while protecting the outstanding values of the Chattooga Wild and Scenic River corridor and whether or not the Chattooga Wild and Scenic River corridor should be open to boating above Highway 28.

The Chattahoochee-Oconee National Forests in Georgia, Nantahala National Forest in North Carolina and the Sumter National Forest in South Carolina share management of about 70 percent of the lands within the watershed. The Chattooga Wild and Scenic River corridor also lies within portions of the three National Forests, with the Sumter being the lead forest for management programs and direction pertaining to the Wild and Scenic River boating and instream recreational uses. Each forest manages the other land based activities within the Corridor. Direction for the wild and scenic river corridor is in Management Prescription 2A for each of the forests, and in Management Area 2 for the Sumter portion of the watershed.

The Chattooga River watershed drains water from an area that intercepts three states and their three national forests. The watershed headwaters in North Carolina begins at high elevations (4,900 feet) where the annual rainfall averages 80-inches-plus and supports a diverse mountain forest characteristic of the Southern Appalachian Mountains. Near its confluence with the Tallulah River, the watershed flows out of the mountains into lower elevations (900 feet) with characteristic Upper Piedmont landscapes.

The watershed covers a total of 180,795 acres in the three states of Georgia, North Carolina, and South Carolina, with national forests comprising 122,192 acres. Within the watershed are rugged mountains, narrow valleys, and rolling hills, each with distinct resources and land uses. A primary value of the watershed is the relatively remote setting, with dense mature pine and hardwood forest within the Chattooga Wild and Scenic River and the surrounding corridor. The river and watershed have been the focus of numerous ecological and recreational studies due to high public interest since its designation by Congress. Three projects in the 1990s emphasized the concerns and benefits of the watershed. The Chattooga River Watershed Ecosystem Management Demonstration Project (1993-1995) brought together scientists and land management agencies to develop a number of analysis tools and reports. Products included a multi-scale ecological classification, basin-wide evaluations of water quality, and a development of desired future conditions for the range of issues in the watershed.

The U.S. Environmental Protection Agency brought together a cooperative effort in 1996 to evaluate water quality conditions within the streams of the Chattooga. As part of a settlement agreement before a U.S. District Court, the EPA conducted an assessment of waters using the latest technology. Techniques and methodologies were used to develop protocols for water quality evaluations useful in any watershed. A result of the project was the listing of several stream segments on the 303(d) list of impaired waters in Georgia. A sediment yield model originated from the studies to be used in addressing total maximum daily loads (TMDLs) assigned by the State water quality agency.

A recent effort to address the restoration of watershed conditions has been the Chattooga River Large Scale Watershed Project, designated by the Chief of the Forest Service in 1999. The large scale watershed project, one of twelve in the United States, organized resources across the watershed to inventory stream conditions, upgrade road conditions, and enlist owners of private lands in addressing watershed conditions. Using data and protocols developed by the previous projects, stream inventories are in process to develop a common aquatic data set of conditions. Several primary roads and trails have been upgraded to address conditions contributing to stream sedimentation. A primary focus of the project has been the participation of owners of private lands in identifying problems and implementing solutions with multiple benefits.

Each of the twelve projects mentioned above has provided data, evaluation models, and insight from the public to address the issue of basin-wide management of the Chattooga River Watershed. Throughout the development of the revised Land Management Plan, the National Forests have worked cooperatively with the state and local governments, and the citizens of the watershed to develop a range of alternatives to move toward desired future conditions for the watershed.

When Congress designated 57 miles of the Chattooga River corridor as a component of the National Wild and Scenic River System on May 10, 1974, they probably had no idea that the river would become a recreation focus and nearly 100,000 people would be floating the river each year. The river corridor and its immediate surroundings offer many recreational uses besides boating, such as fishing, swimming, floating, hiking, horseback riding, camping, and sightseeing in remote–and occasionally in roaded–settings. Recreational boating (kayaking, canoeing, and rafting) has been a popular use of the river and includes both guided and self-guided users. Water quality declines in some sections, especially below the confluence with Stekoa Creek (Georgia) or in relation to storm events in other areas.

The existing boatable portion of the Chattooga River is divided into four sections. Section I is the West Fork of the Chattooga River in Georgia ending at the main river channel. Section II begins at the Highway 28 bridge and ends at Earl's Ford. Section III begins at Earl's Ford and ends at the Highway 76 bridge. Section IV begins at the Highway 76 bridge and ends at Tugalo Lake. The uses of the river are regulated by section, season, water level, and type of use (commercial and private).

The proposed alternatives offer a range of management options for the lands and resources of the watershed. Management prescriptions allocated address old growth, wildlife habitat needs, backcountry, wilderness and roadless, restoration of vegetation associations, provision of high quality water for recreation and fisheries, and maintenance of the wild and scenic river.

In addressing this issue, management activities would strive to accomplish:

- Management of the Chattooga Watershed for desired social and ecological benefits while protecting the outstanding values of the Chattooga Wild and Scenic River corridor.

Table 2-16 shows the comparison of Issue 13 by alternative.

TABLE 2-16. ISSUE 13 – CHATTOOGA RIVER WATERSHED

Issue/Units of Comparison	A	B	D	E	F	G	I
	Dominant						
Management Prescriptions > 5,000 acres (Sumter and Chattahoochee-Oconee NFs)	2A 7E1 7E2 10B 12A	2A 8A2 9A3 9H	1B 2A 9H 10B	1B 2A 7E1 7E2	2A 10A 10B	1B 2A 4F 6C 6A	2A 4I 7E2 8A1 9A3 9H
	Miles						
Miles of Chattooga River opened to boating above Highway 28	10	0	0	20.7	0	0	0

Issue 14 – Minerals

Mineral exploration or development will be compatible with the desired condition of the appropriate management prescriptions or management areas. There are three categories of availability for mineral leasing purposes. The first category consists of lands not available for lease. These lands have either been withdrawn from mineral entry administratively, by law, or the Forest has determined that a prescription goal cannot be accomplished if the lands were open to mineral entry. The second category allows leasing, but there are no-surface-use or controlled-surface-occupancy stipulations attached to any lease issued on these lands. The third category consists of lands that are available for lease with standard lease stipulations.

In addressing this issue, management activities would strive to accomplish:

- Meet demands for energy and non-energy minerals consistent with forest plan management prescriptions.

Table 2-17 shows the comparison of Issue 14 by alternative.

TABLE 2-17. ISSUE 14 – MINERALS

Alternative/Units of Comparison	A	B	D	E	F	G	I
	Percent of Total Forest Acres						
Not Available for Lease	4.2	3.8	2.6	3.5	2.7	3.8	3.0
No Surface Occupancy or Controlled Surface Use Stipulations	24.4	32.5	23.4	36.6	4.4	45.7	33.6
Available for Lease with Standard Stipulations	71.4	63.7	74.0	59.9	92.9	50.5	63.4

Conformance with RPA

The National Forest Management Act (NFMA) regulations at 36 CFR 219.12(f)(6) require forest plans to respond to and incorporate the Renewable Resources Planning Act (RPA) program objectives. The last RPA program was developed in 1995. Currently the Forest Service Strategic Plan (2000 Revision) provides broad overarching national guidance for forest planning and national objectives for the agency as required by the Government Performance and Results Act. All of the alternatives in this EIS incorporate these broad strategic objectives.

CHAPTER 3

AFFECTED ENVIRONMENT AND ENVIRONMENTAL CONSEQUENCES

INTRODUCTION

The purpose of Chapter 3 is to present before-and-after views of the forest environment. It is to discuss the environment as it is currently and as it would be if the alternatives were implemented.

The "Affected Environment and Environmental Consequences" discussions are required by the National Environmental Policy Act (NEPA) that implements regulation under (40 CFR 1500). Each resource is first described by its current condition. These descriptions are limited to the background information necessary for understanding how forest plan alternatives may affect the resource. The resources listed and their sub-headings are designed to address issues raised throughout the planning process.

After each discussion of the current condition of a resource, the potential effects (environmental consequences) associated with implementation of each alternative are discussed. All significant or potentially significant effects—including direct, indirect, and cumulative effects—are disclosed. Where possible, the effects are quantified. Where this is not possible, a qualitative discussion is presented.

Programmatic verses Site-Specific

For estimating the effects of alternatives at the programmatic forest plan level, the assumption has been made that the kinds of resource management activities allowed under the prescriptions will in fact occur to the extent necessary to achieve the goals and objectives of each alternative. However, the actual locations, design, and extent of such activities are generally not known at this time. That will be a site-specific (project-by-project) decision. It is also unsure if the budgets needed to implement the specific activities will be forthcoming. Thus, the discussions here refer to the potential for the effect to occur, realizing that in many cases, these are only estimates. The effects analysis is useful in comparing and evaluating alternatives on a forestwide basis but is not to be applied to specific locations on the forest.

Types of Effects

Environmental consequences are the effects of implementing an alternative on the physical, social, and economic environment. *Direct environmental effects* are defined as those occurring at the same time and place as the initial action. *Indirect effects* are those that occur later than the action or are spatially removed from the activity in the foreseeable future. *Cumulative effects* result from the incremental effects of actions added to other past, present, and reasonably foreseeable actions, regardless of what agency (federal or non-federal) or person undertakes the other actions. Cumulative effects can result from individually minor but collectively significant actions taking place over a period of time.

PHYSICAL ELEMENTS

Soils

<u>Affected Environment</u>

A soil is the part of the Earth's surface composed of organic matter, minerals, and living organisms and is capable of supporting a wide variety of biological, chemical and physical processes, and the cycling of nutrients and water. Soil is the result of weathering of parent rock material over extended periods of time influenced by climate and living matter, conditioned by relief, and effected by both natural events and the cultural alterations or uses of human beings. Soil physical materials consist of sand, silt, clay, and organic matter. Other particle sizes such as gravel, cobbles, and boulders may be included with the soil mixture as a result of past geologic, geomorphic, and hydrologic movements. These materials can be found in various combinations, depths of internal soil features, and development type from residual materials, erosion, or deposition, to form a soil series. Geology, climate, moisture, wind, and hydrologic regimes can have an influence on soils.

The soils on the Sumter National Forest vary between the piedmont and mountain topographic regions. The piedmont soils are formed from crystalline rocks, mixed acid rocks, micaceous rocks, and Carolina slates. The mountain soils are formed from colluvial materials weathered from gneiss, schist rock, and granite materials.
The piedmont soils on the Long Cane and Enoree Ranger Districts consist of 63 soil mapping units, with many of these due to divisions which show past moderate or severe erosion areas. Andrew Pickens District soils consist of 22 soil mapping units. Mapping units have at least 50% of a primary soil series, with the remaining areas consisting of other similar or non-similar areas. The smallest mapping unit is typically 8 acres, so local inclusions of other soil types within a mapping unit may be found.

Soils of the piedmont are located on gently to steeply rolling hills with generally well-drained sandy to mixed alluvial valleys. Due to past cultivation practices, most of the moderate to steep areas have been moderately to severely eroded leaving a thin- to no-surface soil horizon. Even some relatively flat areas have also been affected from old agricultural terraces that have failed, activating the formation of gully channels from the concentrated flow. Soils high in mica content are sensitive to several forest ground disturbing activities due to high erodibility when exposed and the potential for the soil to compact. The B horizon in the piedmont has some resistance to erosion due to the elevated clay levels. However, gullied lands have typically eroded past the soil B horizon, exposing the deeply weathered parent materials (saprolite) in the C horizon. The saprolite materials are incompetent, droughty, nutrient deficient and extremely erosive when exposed to rainfall and/or concentrated flow. Gullies and galled barrens are occasionally found in these severely eroded areas.

The major soil concern on the forest is soil productivity. Soil productivity varies widely due to past erosion severity and varying characteristics such as soil depth, available water holding capacity, nutrient status, and site characteristics including elevation, slope, and aspect. Poor soil productivity not only affects the growth of plants, but also affects water quantity and quality, and biological and other resource capabilities of the land. Gullies and galls that were formed have affected soil productivity by depleting nutrients, water absorption, and availability (Hoover, 1949). There are still erosional gullies, galls, and bare soil found on the Long Cane and Enoree Districts, and to a much lesser extent, on the Andrew Pickens District. The past erosion was so extensive that almost all of the piedmont surface soils have eroded leaving less than 2 inches of soil surface (A horizon) on most of the landscapes. Moderately eroded sites (approximately 192,000 acres) have 1-3 inches of soil surface. Severely eroded sites (over 22,300 acres) have less than 1 inch to no soil surface. These areas will require treatment to improve soil productivity. Soil and water improvements continue to reduce or obliterate the effects of the gullies and severe erosion on National Forest System lands in the piedmont. Without improvements, these and adjacent lands will continue to decline in productivity.

Soils of the mountains are generally well drained, but have a wide range of slope and landform conditions from nearly level to gently sloping areas in the floodplains, gently to steeply sloping areas on side-slopes, with mostly narrow and irregular ridgetops. Some of these soils contain high levels of mica, but not enough to be classified as micaceous. Soils high in mica are highly erosive and are located throughout the district, but tend to have the highest levels concentrated toward the North Carolina border. Site-specific soil surveys may be needed prior to implementing extensive soil disturbing activities. There are differences in the soil series relative to productivity, erodibility and soil stability. These soil differences are based on a variety of factors including geology, soil structure, horizon depths, slope, litter depth, vegetative cover, aspect, and subsurface drainage.

Soil Productivity

Various legislative and executive mandates and Forest Service policies address land productivity. The National Forest Management Act (NFMA) of 1976, Section 6 (3)(E)(i), restricts timber harvest from National Forest System lands to only where "soil, slope, or other watershed conditions, will not be irreversibly damaged". Likewise, Forest Service Regulations (36 CFR 219.14 (a)(2)) limit timber production to lands where soil productivity and watershed conditions won't be irreversibly damaged. Timber must be harvested "in a manner consistent with the protection of soil, watershed, fish, wildlife, recreation, and esthetic resources, and the regeneration of the timber resource." As a safeguard within the act, Section 6 (3)(F)(2), and Forest Service Regulations (CFR 219.27 (a)(1), (b)(5)), require an evaluation of the effects of management and the elimination of activities that may substantially and or permanently impair productivity of the land.

Soil productivity is one of the primary concerns on the forest, and is evaluated using Regional Soil Tolerance Guidance (1982). Existing or potential conditions in the piedmont that influence soil productivity include soil type, aspect, erosion potential, nutrient status, and past land use. Soils in declining or unsatisfactory watershed conditions are especially sensitive to land use changes, wildfire, and intense storm events. Rejuvenation of severely eroding lands in the piedmont has the potential to increase soil erosion, water pollution, and downstream sedimentation; reduce site productivity for timber and certain wildlife species; and reduce the local water table. Flooding severity may increase if soil conditions are not maintained, enhanced, or improved (Hoover, 1949). Downstream impacts may include sedimentation and loss in channel capacity. The inventory of eroding and low productivity lands will be updated and included in the Watershed Improvement Needs Inventory (WIN) database. Existing inventories show about 2,000 acres of eroding lands needing structural treatment. This is not a complete inventory of needs and does not include streambank and channel improvements that have not been inventoried. Nutrient deficient lands needing fertilizer treatment are estimated at 28,000 acres. Other areas needing improvements may also be located during project reconnaissance or acquired through land exchange or purchase. Soil or watershed conditions in poor and/or declining conditions will be assessed and treated. Besides stabilizing severe erosion, native plants are being used to help achieve long term erosion control, build soil organic matter, enhance responses to natural disturbances, improve poor soil conditions, increase resilience to disturbance (flooding, fire, drought, insects and disease) and provide low maintenance needs (Law et. al., 2000).

There are four productivity classes on the forest that describe the capability of an area. Productivity classes I and II are fertile, well drained soils located on broad ridgetops on most of the piedmont. They include a small percentage of class I and II lands in floodplains that are poorly drained to very poorly drained. Most of the soil in productivity classes III and IV are lacking a soil surface layer and produce less than desired surface cover and vegetative health. Most soils of the piedmont have low nutrient levels. In general, soils are well developed with deep profiles, shallow A horizons and organic surface layer and good hydrologic condition. The piedmont districts have approximately 12% productivity class I acreage, 54% class II acreage, 22% class III acreage, and 12% class IV acreage.

Productivity classes I and II in the mountains are fertile soils usually located on northern and eastern aspects with deep soil profiles (40-inches-plus) and a well developed organic and A horizon. Also, all of the floodplains and wetlands are found in productivity classes I and II. Productivity classes III and IV are low in fertility, usually located on southern and western aspects with moderately deep soil profiles (less than 40 inches), and shallow developed A horizons with little or no organic accumulation on the surface. Rock outcrops are occasionally found on the soil surface. Colluvial soils are especially susceptible to land slippage and need care in location and design of activities such as road building. The mountains have approximately 25% productivity class I acreage, 28% class II acreage, 37% class III acreage, and 10% class IV acreage.

Fertilization or other treatments may be required on productivity III and IV lands to maintain and improve watershed condition. Fertilization increases the health of the trees, understory vegetation, and root structure that tie up nutrients and eventually contribute to organic and nutrient cycling increases in the litter and surface soils (McKee and Law, 1985, McKee et. al., 1995). Approximately 28,000 acres of eroded, low site lands in the piedmont of South Carolina need to be fertilized. Fertilization improves both the understory cover and variety and health of existing trees. Without fertilization, understory vegetation is marginal and pine mortality is higher due to their lack of vigor and increased susceptibility to insects and disease. Fertilization on these lower site pine lands enables the pine trees to grow until stand regeneration age or in some instances, even older ages, which helps meet mature timber habitat goals. On low site lands, thinning and harvest activities try to retain an even distribution of limbs and other organic debris in place when harvested. When prescribed burning is considered, only low intensity fires are desired in order to retain duff and humus layers, except where dense stands of native grasses or other resilient cover have developed or been planted. Without fertilization, many of these areas cannot meet their physical and biological potential.

Some concern exists that the non-native plants will outperform native species when fertilization occurs. Persistent and invasive non-native plants are being avoided. Containerized growing of many native grass, shrub, and tree species from the Sumter National Forest have shown that they also respond exceptionally well to fertilization (Law et. al., 2000). Where cover crops of non-native species are needed, annuals or species that do not persist are selected so they do not out compete the native species. Since many of the non-native species do not respond well to prescribed fire, while the native species flourish, fire is a likely tool that might be increased when understories remain dominated by non-native species. The goals of fertilization are to provide a needed shot of the nutrients that are extremely deficient in the soil in order to improve the short-term absorption and assimilation of nutrients into the soil cover, increasing soil organics and plant health.

Various programs assist in protecting, improving, and maintaining soils so they can accommodate a variety of resources. Soil and water improvements help to address existing problems that are not a direct result of past or ongoing forest programs. South Carolina Best Management Practices (1994) include some soil conservation measures that help protect soil productivity from excessive erosion and disturbance. Timber harvesting includes provision for protection and improvements to soils and water resources through the Knutson-Vandenberg Act as amended in the National Forest Management Act of 1976. With these and other programs, soil and water conservation improvements are evident. Utilization of erosion control practices such as seeding, mulching, fertilizing, liming, and maintaining forest and grass cover improve site productivity, especially on exposed, compacted soils of the forest. As a result of these programs, areas of bare soil, gullies, galls, eroding stream banks, non-system roads and trails, and other areas needing improvements show an increase in vegetative cover and stability. As vegetative cover increases, litter and duff layer continue to accumulate, decompose, and help establish an organic layer. Improving the organic materials to a functional level is key to nutrient storage and availability for plant growth and watershed protection. Organics improve water absorption, infiltration, storage, and availability that add to soil productivity and to resistance to soil erosion.

Activities Affecting Soils

The resource management areas that have an effect on the soil resource are Vegetation, Wildlife, Recreation, Fire, Roads, Minerals, and Special Uses. Elements within these resource management areas may affect soil productivity through a variety of processes including soil compaction, displacement, rutting, stability, erosion, and topsoil removal. These processes may alter aspects of how the physical, chemical, and biological properties of soil function. These alterations can influence nutrient, water, chemical, and air cycling within the soil. The application of forest standards and guidelines and the use of South Carolina Best Management Practices will minimize impacts on soil productivity and reduce soil erosion when implemented properly and in a timely manner.

Ground disturbing activities may influence soil productivity by compaction, soil displacement, slope stability, rutting, erosion, and topsoil removal. Most activities utilize preventative measures such as best management practices (BMPs) to limit or mitigate these effects through the management of where, when, and how activities are placed on the landscape. Some soil and water improvements are undertaken that may temporarily cause effects by exposing and recontouring problem soils, with the long-term intent to increase stability and function. In general, unless strict erosion control plans are in place, activities on treated areas should disturb or expose no more than 15% of an area. Areas that are reshaped or recontoured are aggressively treated to minimize erosion and sedimentation. A variety of measures are used to accomplish stabilization and restoration of problem gully, road, galled, and other sites (Hansen, 1991, 1995; Hansen and Law, 1993, 1996; Law et.al., 2000).

Type of Soils

Compaction is the reduction of soil volume due to an external force such as from the use of heavy equipment on moist soils, which results in alteration of soil chemical and physical properties. Soil compaction alters soil structure by decreasing macro pore space and soil porosity. This reduces productivity by retarding root growth as well as air and water/nutrient transfer in the soil. Surface soil recovery from compaction is relatively rapid on sandy soils, but may take decades to recover on soils with clay near the surface unless some form of mitigation is used. Periodic freezing, thawing and fertilization can increase the rate of recovery. Any activity requiring the use of heavy equipment can cause some degree of compaction, but excessive compaction is often related to certain soil types and moisture levels.

Soil displacement moves soil surface material from its original position on the landscape. The displacement typically is small, perhaps a few inches to a few yards and often has a vertical and horizontal component from the original location. It can alter the rich organic and mineral surface soil layer from one place to another through mechanical means (e.g., skidding of logs, blade construction of skid roads, landings, temporary and system roads, ATVs, etc.). It can also accelerate erosion and reduce nutrient supplies, which are all important to plant growth. On saturated soils, soils may reach their plastic limit and displace under the weight of heavy equipment. Excessive activity on saturated soils can also cause soil puddling, which is the breakdown of the soil structure bonds, resulting in soil particle displacement and mixture with water. Puddled soils make a poor growing medium because the pore structure is broken, air permeability is limited, and the soils retain water for extended periods. When dry, puddled soils have lost their soil structure and often develop deep cracks in the soil surface, making a very poor site for plant establishment and growth. Most plants have a difficult time rooting and growing under those conditions.

Slope stability is the capability of a soil to maintain its original position on the slope. Unstable soils in the mountains are typically colluvial soils. These soils are limited in extent, but may contain elevated groundwater or subsurface concentrated flow during wet periods that make them subject to slippage and slumpage when vegetation is removed or slope altering activities such as road construction and skidding are undertaken. This can potentially initiate or accelerate soil mass movement by undercutting, overloading a slope with subsurface water, or disrupting established subsurface drainage patterns. Areas with soil slope stability problems can affect roads, ability to harvest, and other activities.

Rutting is the destruction of the soil structure caused by heavy equipment loading and indentation into the soil surface. During dry conditions, rutting is less frequent and occurs mostly in isolated moist areas, or on primary skid trails where repeated skidder traffic gradually compacts the soil into an indenture in the landscape. When certain soils are moist and/or wet, rutting can be a significant problem, especially if natural regeneration methods are planned. It also changes the native plant communities on the area. Rutting is a highly visible impact of logging and can disrupt the normal hydrological flow of surface and subsurface water. Careful planning of activities will eliminate or minimize this effect. When activities cannot avoid sensitive soils, designed activity routes should be located prior to starting work to limit the extent of the effect.

Erosion is a natural process that dislodges soil particles and moves them. Soil exposure can be a result of natural and human-induced conditions. Exposed surface soil particles move during events with external forces such as rainfall, stormflow, and wind events. Forested soil is an excellent filtering mechanism that may absorb contaminants, preventing their entry into streams. However, when eroded, soil particles may include contaminants and may add to stream pollution upon delivery. Erosion that reaches the stream network is moved as a portion of the total dissolved solids or precipitates out temporarily-to-semi-permanently as sediment. Careful design and use of BMPs can reduce both erosion and sedimentation.

Productivity is the composite of the compaction, displacement, rutting, slope stability, and erosion effects on soils. Most of these effects go unnoticed, unless a threshold is reached. Region 8 has guidance to address erosion loss and set standard estimating approach (USFS, 1992). In addition, the loss of nutrients or organic materials can change productivity. Productivity loss can typically be reclaimed with treatment, but at a cost and with sometimes years or decades of recovery.

Direct/Indirect Effects

Roads and Trails

A road is a motor vehicle travelway over 50 inches wide, unless designated and managed as a trail (36 CFR 212.1). A road may be classified, unclassified or temporary.

Classified roads are wholly or partially within or adjacent to National Forest System lands that are determined to be needed for long-term motor vehicle access, including State roads, county roads, privately owned roads, National Forest System roads, and other road authorized by the Forest Service. Characteristics of classified roads vary with the amount and frequency of traffic, but they are specifically designed and located to meet long-term needs, with culverts sized to limit flood risk, road surfacing for traffic, adequate drainage and erosion control to limit sediment, and are maintained regularly with the frequency depending on their design, uses and conditions.

Unclassified roads found on National Forest System lands are not part of the forest transportation system, such as unplanned roads, abandoned travelways, and off-road vehicle tracks that have not been designated and managed as a trail; and those roads that were once under permit or other authorization and were not decommissioned upon the termination of the authorization. In most instances, the extent of unclassified roads are not completely known at this time, but they will be identified and evaluated in the Roads Analysis process during implementation of project activities to determine if they should be added to the system as classified roads or decommissioned.

Temporary roads are authorized by contract, lease, other written authorization, or emergency operation; not intended to be part of the forest transportation system; and not necessary for long-term resource management. Characteristics of temporary roads include low standard, minimum width, generally single use facilities to access an area and are sufficiently blocked to not allow any continued use by vehicular traffic or provide permanent road access. The road will be stabilized to prevent erosion, sedimentation and restored to near original condition after use by seeding or tree planting typically resulting in fully vegetated surfaces with no erosion or sediment within three years. These roads may not be designed to classified standards, and culverts, surfacing and other structures may be inadequate for extended uses. Since these roads are not maintained, removing unstable or problem cuts, fills and culverts are necessary in streams, channels, wetlands, steep slopes and other sensitive areas.

Roads and trails expose and compact soils, alter surface and subsurface water flow patterns, and can alter stream channels during and following construction. Roads and trails directly and indirectly affect water by increasing sedimentation and concentrating runoff. Direct effects to soil and hydrology are excavating and compacting soils, filling, placing culverts, and using equipment in streams, riparian, and other sensitive areas. Stream alterations include channel confinement such as into a culvert with a localized loss of flood-prone areas, and inputs from road surface drainage that include added storm-water, sediment, and road traffic pollutants. Open roads contribute higher erosion and sedimentation rates due to ongoing maintenance activities such as surface scraping and shaping, ditch pulling or scraping, and normal wear and tear on the road surface from use. Road surfaces may also contain low levels of vehicle petroleum product pollutants that can be flushed into the aquatic systems during storm events.

Activities associated with closing roads and trails stabilize the road surface when properly drained and vegetated. Some flatter road and utility corridors are lightly disked to break the surface, then reseeded and mulched to provide linear wildlife strips. Some road closures may inadvertently leave in culverts or other road structures. These can become problems unless they were sized for permanent use and maintained. Roads and trails often create problems when located in riparian areas because they are difficult to drain, cause excessive compaction or displacement of soils, alter normal surface and subsurface flows, and increase pollution to streams.

Road and Trail Effects

Average erosion coefficients for construction of classified and temporary roads in this analysis were 54.9 tons/acre in the mountains and 2.66 tons/acre in the piedmont. Classified roads addressed in this analysis are the Forest Service system roads used for recurring and ongoing access needs. They are maintained and may be open, closed and reopened as needed, or seasonally open. Temporary roads are used to meet short term, non-recurrent needs. Reconstruction and maintenance activities for permanent roads were 23.4 tons/acre mountains and 1.13 tons/acre piedmont. The number of acres per road mile ranges from 2 acres/mile of temporary road with effects lasting normally about 3 years to over 5 acres/mile of permanent system road with ongoing effects. Existing foot and mountain bike trails averaged 1.42 tons/mile/year with 2.84 tons/mile for new trail construction. Horse trail construction averaged 14.1 tons/acre/year/mile with existing horse trails producing 7.04 tons/acre based on current trails in the piedmont and mountains averaging about 1 acre per mile of trail. The erosion coefficients for OHV/ATV trail construction (all occurs in the piedmont) were 5.68 tons/acre and existing 2.84 tons/acre, with about 1 acre per mile of trail. Road and trail coefficients were provided by Clingenpeel and Krieger (2002) from examples by physiographic area measured for SA forest plan revision. These estimates do not include off trail or unclassified road uses that are unauthorized and can be substantial in some instances.

Measures to rehabilitate unclassified roads and trails are implemented to block usage and reduce associated erosion and sediment.

Road and Trail Management Effects by Alternative

Estimated erosion effects by alternative for system road construction, reconstruction, maintenance, and closure activities indicate Alternatives G and E have the least erosion with 4,800 tons/year (t/y), with Alternatives A, B, D, F and I at 4,900 t/y, over the first decade. Addressed with other units and spread over the national forest, the 4,800-to-4,900 tons/year variation of erosion effects from trails is 8-9 tons/square mile/year, which is 0.01 tons/acre/year.

Trails produce less impacts with Alternatives B, D, F and G at 820 tons/year, Alternative I at 1,900 tons/year, and Alternatives A and E at 2,300 tons/year. Addressed with other units and spread over the national forest, the erosion effects from trails is 1-4 tons/square mile/year, which is less than 0.01 tons/acre/year.

Temporary roads were primarily associated with vegetation management activities, and their effects range from 6,900 tons/year for alternative G to 14,800 tons/year in alternative E, with Alternative I at 13,100 tons/year. Erosion from temporary roads ranged from 12-26 tons/square mile/year or 0.02 to 0.04 tons/acre/year.

The sediment effects of roads and trails to water resources were included with other activities estimated at watershed scales in the water quality effects section using the regional sediment model (Clingenpeel, 2002) and applying localized erosion coefficients (Hansen and Law, 2002).

Vegetation Management

Vegetation management activities that affect soil and water are timber harvesting, temporary roads, site preparation, timber stand improvement projects, skid trail construction, and felling, yarding, skidding, loading, and transporting logs. Most of these effects are temporary, lasting only a few years. Loss of the protective soil cover (litter) from ground disturbance can temporarily increase erosion and sedimentation while decreasing soil productivity. Chopping is typically used for site preparation on many of the slopes under 25% in the piedmont, and this activity can cause some temporary soil disturbance, exposure, and erosion. Various aspects of vegetation management can influence soil, water, and riparian conditions as summarized in various sections of the R8 Vegetation Management Plans (USFS, 1989). Activities under this section include many actions that are needed to maintain, manage, or manipulate vegetation densities and types to improve forest health and wildlife habitats.

Studies indicate that nutrient losses from timber harvests can be comparable to nutrient inputs, resulting in no long-term reduction of the ecosystem's productive potential (Kimmins, 1977; Wells and Jorgensen, 1978; Patric, 1980; Grier et. al., 1989). Nutrient losses from timber harvest were found to be small to negligible, with losses such a small fraction of total nutrient capital that site productivity should not be reduced (Sopper, 1975). Only where timber harvest is coupled with piling or windrowing of slash and all other woody and organic material on the forest floor by mechanical means, can demands on the soil potentially exceed the natural nutrient supplying capacity of the system. Intensive site preparation practices would exceed the regional soil tolerances for erosion and are no longer used for timber production activities on the national forest nor on most of the private and industrial lands. On private lands, site preparation with herbicides is now the standard method.

Water yields change somewhat when vegetative removal or conversion to pasture or grassland occurs because of reduced transpiration and raindrop interception (Hibbart, 1965; Hewlett and Hibbart, 1965). Typically, pine forests use more water than hardwood forests or grasslands. Activities that regenerate forests will typically cause some water increases for up to a decade, with increases in flow primarily during the base or low-flow periods. Roads, trails, and similar activities related to these uses are more likely to decrease low-flow and increase the quick or storm-flow values. These effects are most noticeable on localized scales and not normally at the watershed or landscape scales with normal forestry management that disperses activities over time and space. When water yield effects occur, they commonly last 5-to-10 years unless the forest is converted to another species type or land use. Some reduction in flows may be noticed during periods of rapid growth in young stands between 10 and 20 years of age (Swank et. al., 2000).

Vegetation Management Effects

Timber harvest can release nutrients bound in the soil and biomass by increasing organic material to the forest floor, increasing sunlight to the forest floor, increasing soil temperatures and resulting decomposition rates. Most areas regenerated in the piedmont with slopes under 25% will be drum chopped. Erosion from this activity depends on slope and ranges from 0.1, 1.1, and 2.5 tons/acre on slopes of 2, 15, and 25%, respectively. Areas converted to savanna or woodland will be burned on fairly frequent cycles to mimic the natural processes to restore native plants and grasses into the understory at high densities. Native grasses help to provide quality erosion control and resilience to fire, drought, and nutrient deficiencies. As organic matter levels rise, soil micro-organisms play an instrumental role in the conversion to humus, a relatively stable form of carbon sequestered in soils for long periods (decades and even centuries). Soils in the proposed treatment areas in all alternatives are capable of retaining released nutrients rather than losing them through drainage or volatilization. Timber harvest practices occur at infrequent intervals and will generally maintain soil productivity with close attention to BMPs. Clear and seed tree cuts lose only 5.8 tons/acre in soil loss on moderate slopes, to 8.9 tons/acre on steep slopes in the mountains, and 3.2-to-4.9 tons/acre in the piedmont (localized data from Dissmeyer and Stump, 1978; Goddard, 1982). One-third to one-half of these values is the estimated erosion from the skid roads and trails. Thinning, group selection and shelterwood cuts produce about 30-to-60% of the soil loss rates of the even aged regeneration cuts.

Because of southern pine beetle (SPB) infestation, continued pine cutting with leaving or removing trees helps to reduce the spread rate from that spot. Removing trees in salvage timber offers better opportunities to regenerate these areas, reducing the excess fuel buildup and fire hazard. Where salvage is viable, some of the sale funds help maintain or close roads and provide for soil, water, and other resource improvements when sufficient funds are available.

In contrast to the potential effects of logging on productivity and nutrient cycling, timber fallen, windblown, or killed by pests and diseases, if left-in-place would over the long term improve local soil productivity. As timber decays, it enhances many biological processes and physical attributes important for soil development and management.

Vegetation Management Effects by Alternative

Estimated erosion effects by alternative for probable vegetation management activities including temporary roads and skid trails indicate Alternative G has the least erosion with 20,500 tons/year; with Alternative B producing 37,100 tons/year; E, 35,600 tons/year; I, 35,300 tons/year; D, 35,300 tons/year; A, 37,400 tons/year; and F, 41,700 tons/year over the first decade. Addressed with other units and spread over the national forest, these values range from 35-to-73 tons/square mile/year, which is equivalent to 0.06-to-0.11 tons/acre/year. The sediment effects of vegetation management to water resources were included with other activities estimated at watershed scales in the water quality effects section using the regional sediment model (Clingenpeel, 2002) and applying localized erosion coefficients (Hansen and Law, 2002).

Fire Management

Historically, wild land fire is a natural component to the landscape, and can occur under a variety of conditions. Under some conditions, wild land fire is beneficial by removing fuel buildup and promoting a mosaic of wildlife habitat, rejuvenating some areas for rapid regrowth. Wild land fire can also produce undesired effects to adjacent landowners and the environment, e.g., suppression activities can have direct and indirect soil and water effects primarily from the location and construction of fire lines and firebreaks. Fire lines have many of the effects of skid roads, and mitigation measures to limit their effects are similar. Fire lines expose mineral soil, and when designed with drainage features such as rolling dips, flow is removed and dispersed into the forest and effects from erosion and sedimentation are limited. There is often little or no time to plan the best route for constructing fire lines, so mitigation following suppression activities is also important.

Under extreme circumstances that produce a severe burn, all or almost all of the litter, duff, and humus on the forest floor would be consumed, vegetation killed, and mineral soils exposed. Burns of this intensity are unusual occurrences and seldom found across large areas. In localized instances, the mineral soil may degrade by particle fusion or develop a non-wettable soil layer that can restrict water infiltration until it breaks down. Severe burning can affect soil biota, structure, organic matter, and fertility, potentially triggering accelerated erosion and cycling of soil nutrients. Suspended solids, sediments, ash, and nutrients in streamflow might temporarily increase to unacceptable levels in nearby streams during storm runoff events.

Prescribed burning is designed to burn with less intensity with less direct and indirect effects to soil and water by removing much of the vegetative cover and litter, while protecting the duff and humus layers of the soil. Under most prescribed burning plans, only a small portion of the soil may be exposed, which may cause concentrated surface flow, erosion, and sedimentation. Prescribed burning goals include measures to maintain soil productivity and erosion control by protecting the duff and humus layers on the soil surface. Further measures as needed to provide erosion control include fertilization, seeding, and mulching. Low intensity burns typically do not reduce soil productivity or substantially increase stream sedimentation (R8 Vegetation Management Plans for Mountains and Piedmont, 1989). However, effects can increase substantially as the burn intensity increases, but these depend also on the soils, slope, topography, rainfall, and cover factors. Fire lines often produce more effects than the fire. Properly designed fire lines effectively limit effects to soil and water resources. These can be designed for reuse in areas of frequent burning cycles. Location, water, and erosion control are key components in limiting short and long term effects to soils and water resources. Rescraping the surface lightly when the area is to be reburned will reduce effects when compared to relocating and reconstructing new firelines. Quality fire lines also allow access during burning and erosion control activities for cost, safety, and environmentally effective treatments. With prescribed fire activities, fire lines can be placed more carefully on the landscape prior to or during construction activities than those constructed for wild land fire suppression.

Prescribed Fire Effects

The effects of prescribed fire on soil productivity can vary with soil conditions (e.g., antecedent soil moisture), soil properties and qualities, as well as the type, extent, intensity, and duration of the burn based on fuel loads and conditions. Published scientific studies have concluded that prescribed burns, implemented under managed or controlled conditions, have negligible effects on the physical, chemical, and biological properties of soils and soil productivity (Ralston and Hatchell, 1971; Johnson and Cole, 1977; Kodama and Van Lear, 1980; Richter, Ralston, and Harms, 1982; Douglas and Van Lear, 1982; Van Lear and Johnson, 1983; Van Lear, 1985; Van Lear et. al., 1985; Van Lear and Danielovich, 1988; Sanders and Van Lear, 1988; Van Lear, Thomas, and Waldrop, 1989; Van Lear and Kapeluch, 1989).

Prescribed burning is primarily low intensity, with perhaps minor portions at a moderate intensity. Areas that are burned hotter are usually in upland areas away from streams. Furthermore, there is little evidence that sedimentation increases significantly in streams from forested lands burned under conditions specified in an approved plan to meet wildlife, recreation, watershed, vegetation management, or ecological objectives. Under these conditions, prescribed burning must retain most of the duff and humus layer on the soil surface. Prescribed burning is much less likely to increase erosion than mechanical methods of vegetation removal or intense wild land fires, which may result in stand damage or replacement. Intensities and durations of soil heating from prescribed burns are designed to be considerably less than those generated by wild land fire.

Prescribed burning has some low to moderate effects on nutrients and soil productivity, depending on slope and fire intensity. As native grasses and plants come to dominate the understory vegetation, organic content in the surface soils typically increases and soil productivity is improved at a faster rate than with forest management alone. Repeated burning at low intensities will generally maintain soil productivity, losing only 0.17 tons/acre on moderate slopes to 0.50 tons/acre on steep slopes in the mountains and 0.07-to-0.20 tons/acre in the piedmont (localized data from Dissmeyer and Stump, 1978; Goddard, 1982).

Historic Wild Land Fire Effects

Under historic wild land fire conditions, it was estimated that about 10% of all acres would be severely burned, with 40% moderate and 50% low intensity. When considering the estimated natural wildfire erosion effects at landscape scales, resulting in approximately 0.04 tons/acre/year in the piedmont and 0.11 tons/acre/year in the mountains, the overall effects of the prescribed burning activities are reduced (Barrett, Kerr, and Hansen, 2002).

Prescribed Fire Effects by Alternative

For prescribed fire, it is estimated that 2% are severely burned areas which have temporary soil exposure, with the remaining 13% has a moderate burn with infrequent areas of soil exposure and 85% low intensity burn with essentially no exposed soils. Over the first decade, it is estimated that temporary soil exposure from the minor areas that are severely burned would occur on about 200 acres per year in Alternative G; with about 400 acres/year for Alternatives A, D, F; nearly 500 acres/year for Alternative I; and close to 700 acres/year for Alternatives B and E. These areas of temporary soil exposure are typically in small patches and well distributed elements within the landscape. As mentioned, areas of more intense burn are usually in upland areas, away from streams.

Erosion is temporarily increased but relatively minor from prescribed fire when conducted at low intensity. Since almost all of the area is burned at low intensity, erosion estimates for the alternatives assumed low intensity prescribed fire. Rates from fire were based on 0.13 tons/acre with additions for fire lines based on 5 acres/1000 acres treated averaging 11.2 tons/acre. Estimated erosion from probable prescribed burning treatments including fire lines indicated that Alternative G has the least erosion from national forest management activities with 1,900 tons/year. Alternative D has 3,700 tons/year; A, 3,600 tons/year; I, 4,400 tons/year; F, 3,600 tons/year; B, 6,100 tons/year; and E, 6,200 tons/year over the first decade. Addressed with other units and spread over the national forest, these values range from 3-to-11 tons/square-mile/year, which is equivalent to 0.005-to-0.02 tons/acre/year.

It is projected that the prescribed fire program could potentially have some localized temporary adverse impact on soils. These high and moderate intensity areas are normally well-distributed local patches throughout the burn area, but typically not in riparian areas. The sediment effects of prescribed burning to water resources were included with other activities estimated at watershed scales in the water quality effects section using the regional sediment model (Clingenpeel, 2002) and applying localized erosion coefficients (Hansen and Law, 2002).

Wildlife and Habitat Management

A variety of treatments is used to manipulate vegetation to meet specific wildlife and biotic viability, habitat, public hunting, or observation activities. Most of these areas include some form of road or trail access and are located on relatively flat lands under 8% slope, where erosion is relatively low. Constructing sites from forest areas may include activities such as clearcutting, stumping roots, piling debris, smoothing, disking, fertilizing, seeding with desires and/or native species, and mulching. Many of these sites were developed from lands that were farmed prior to being acquired in the 1930s. Most access to openings occurs on existing roads of past use. Some of these areas are probably prime farmlands, but none of the activities being utilized would change this status. New construction require access with current standard, but suitable existing access would be utilized as possible. Problem access roads or routes would be upgraded as needed to limit erosion and sediment effects. Maintenance activities regularly include mowing and infrequent burning when contained within prescribed fire treatments. Regular treatment with fertilizer or selection of nitrogen-fixing plants in the seed mixture help to maintain productivity. Increased use of native plants is encouraged and may result in less intense maintenance and maintenance of soil cover and roots. Other erosion reduction measures include using contour, no- or low-till, and leave-strip treatments.

Cultivating, disking, or breaking the soil surface is used on a portion of the wildlife opening areas at about 3-year intervals on dove fields, select wildlife food plots, and linear wildlife strips on relatively flat sections of closed roads and transmission lines. Fertilization, seeding, mulching, and other erosion control measures are necessary in order to maintain soil cover and nutrients and to limit erosion and sediment, especially on sites with slopes over 3% slope that are repeatedly treated.

Woodland and savanna conversion and management necessitate thinning areas to low basal areas in conjunction with conducting frequent burning cycles. The timber harvest effects were discussed under vegetation management. Short-term effects from frequent burning will include reduction in litter, duff, and humus layers, with eventual development of native grass and shrub understories. Once developed, native grasses are more resilient, require less maintenance, and can withstand more or are not as susceptible to disturbance (such as fire, drought, insect, disease, and poor sites) as most non-native species. Once developed, native grasses have dense root networks that help to increase soil development, organic content, and productivity. Areas converted to woodland and savanna management may include some short-term increase in base-flow, erosion and sediment, and long-term site productivity. Areas burned with moderate intensity will affect soil productivity if on steep slopes. Areas burned with severe intensity will influence soil productivity on all but relatively flat slopes.

Cane restoration, water bird habitat development, thinning, and other probable activities are planned at various levels by alternative within selected riparian areas outside of the streamside management zone. Cane restoration activities within the piedmont will include timber thinning and prescribed burning within the riparian area. In some instances, timber will be girdled and left standing to create openings, but will avoid impacting the area by building access and removing trees. Under acceptable conditions that protect riparian resources, commercial sales may occur. The effects of these activities will be similar to uplands except that there will be more stringent equipment limitations to reduce soil compaction, displacement, and exposure. The effects are sometimes less intense in the flat riparian soils due to high organic content and low slopes. Due to the proximity to streams, impacts from rutting, erosion and sediment are still possible if attention is not given to implementing BMPs during dry soil conditions and maintaining low disturbance of the riparian filter zone.

Water bird habitat developments are typically located within the floodplain or riparian terrace of larger rivers and streams. Existing waterfowl habitat management areas occur on Duncan Creek, Tyger River, Enoree River, and Broad River. Dikes are installed to retain water on these areas and water control measures are often included. Other activity by beavers has also produced some areas that contribute to the extent of this habitat on the piedmont districts. On occasion, small dams and ponds in headwater or small stream circumstances have created some localized water bird, salamander, or other habitats. Among other issues, fish and aquatic organism migration is a concern with these developments. In some instances, cultivation of adjacent lands may be included to increase food plantings and public hunting opportunities, with effects to soil productivity, water quality, and aquatic habitats carefully weighed. Activities will be designed and maintained to meet the intent of Executive Orders 11988 on Floodplain Management and 11990 on Wetland Management. Structures in the floodplain will address the 100-year floodplain for hazards and design needs. Structures will avoid, minimize, or mitigate effects to jurisdictional wetlands, navigable waters, and other waters of the United States. Appropriate state and Federal permits will be obtained as required. Considerations relative to riparian and aquatic habitats, water quality, and other resources will have to be evaluated on a case-by-case basis.

Wildlife Management Effects

Some intensive treatment methods are employed on localized areas to provide early successional wildlife habitats by converting forests to openings. Practices may include clearcutting, shearing, stumping, root raking, piling, burning piles or debris, ripping, cultivating, disking, liming, fertilizing, seeding, and/or planting. Some of these areas are maintained by disking regularly, but most are prescribe burned or mowed a few times each decade. Herbicides are sometimes needed to treat undesired invasive plants. These practices are typically employed on small areas of flat lands of under 4% slope where the erosion coefficients do not exceed the regional soil productivity guide. If these practices are proposed on steeper lands between 5-8% slope, the soil erosion tolerance factors are evaluated to assure consistency with erosion and productivity guidelines, as disking on slopes of 4-8% slope can produce about 4.5-to-11 tons/acre of soil loss (localized data from Dissmeyer and Stump, 1978). Disking on a regular schedule has estimated soil losses of 22-54 tons/acre on these slopes over a decade. Other individual treatments over time can add substantially to this soil loss, making fertilization, planting nitrogen-fixing plants, contour, leave strips, no-till, and other mitigation measures necessary to maintain soil productivity. Only a small portion of the soil loss typically leaves the site, as much is deposited within the treatment area or within adjacent forested buffer strips.

Restoration of cane breaks may include a thinning to a low basal area and two prescribed burns per decade. Estimated erosion is about 1.23 tons/acre/decade for slopes averaging 2% slope in the piedmont. If the thinned trees are girdled and not removed, the effects are only about 0.08 tons/acre/decade for two low intensity burns.

Water bird developments typically modify the existing hydrologic conditions on small to moderate size areas, typically 10-20 acres with unusual sites reaching 50 acres in size. In some instances, these may affect the migration of aquatic species and the distribution of some species such as freshwater mussels that rely on a specific fish species for part of their life cycle. High concentrations of water birds can produce problem levels of water pollutants that may be of concern in some instances when discharged into streams or in municipal or community water systems (Dissmeyer, 2000). Developments that use water levels and other less intensive methods to manage native and desired non-native vegetation species are more likely to have lower effects to soils and water quality than those that cultivate, disc, or employ frequent soil disturbance to control plant species. Since access to these areas is needed during construction, the effects of about 0.1 mile of road per acre of water-bird-habitat developed were included in the estimate of effects below.

Wildlife Management Effects by Alternative

Wildlife management activities include constructed and maintained openings, water bird developments, and canebrake restoration that range upward from Alternative G, which has the least erosion with 1,200 tons/year. Alternative B has 2,900 tons/year; I, 4,400 tons/year; A, 4,599 tons/year, D, 4,600 tons/year; E, 6,700 tons/year; and F, 7,400 tons/year over the first decade. Addressed with other units and spread over the national forest, these values range from 5-13 tons/square-mile/year, which is equivalent to 0.1-0.2 tons/acre/year.

The sediment effects of wildlife activities to water resources were included with other activities estimated at watershed scales in the water quality effects section using the regional sediment model (Clingenpeel, 2002) and applying localized erosion coefficients (Hansen and Law, 2002).

Recreation Management

Roads and trails for accessing areas are a part of recreation management, but these effects were discussed in a previous section. Developed and concentrated use sites expose and compact soils, alter surface and subsurface water flow patterns, and can alter stream channels during and following construction. These activities can increase erosion, sedimentation, and runoff. Occasionally ATV, horse, and other uses do not stick to designated trails and cause increases in soil exposure, compaction, displacement, erosion, sedimentation, and productivity loss. Reclamation of these impacts is costly and detracts from other management activities.

Riparian and stream areas are often a desired focal point of many recreational activities. People love the sights, sounds, life, and movement associated with streams and riparian habitats. However, riparian areas and streams are often very sensitive in a physical and biological sense to many activities that people enjoy. Activities involving concentrated people or animal uses, heavy equipment or horses, generally create problems in riparian areas because compaction or entrenchment produces effects due to limited drainage and excessive holding of water. Damage to tree roots from compaction can reduce health and increase mortality. Indirect influences in some areas include increased erosion, sediment, and stream temperature. Some of these effects can be minimized or mitigated.

Since many of the activities proposed in the forest plan result in impacts to the soil and water resources, the individual effects will be analyzed, compiled, and addressed in the following sections. Some effects will be included with the cumulative effects sediment assessment at watershed scales. Other scales may be mentioned, but are generally not addressed at great detail in this document. Local, onsite, and drainage or tributary scales will be addressed as appropriate with project level activities. At this watershed or landscape scale of planning, the following discussions may seem somewhat general in nature, more qualitative than quantitative, more inclusive of the major activities with less attention to minor ones.

Recreation Management Effects by Alternative

The effects of recreational use roads and trails were included in the roads and trails section. Estimated effects based on recreation use from developed sites (PAOT) and dispersed uses indicate that Alternatives F, B, D, and G have the least use with 800 tons/year. Alternative I has 1,900 tons/year and Alternatives A and E have 2,300 tons/year over the first decade. Addressed with other units and spread over the national forest, these values range from 1-to-4 tons/square-mile/year, which is equivalent to 0.002- to-0.01 tons/acre/year.

The sediment effects of recreation to water resources were included with other activities estimated at watershed scales in the water quality effects section using the regional sediment model (Clingenpeel, 2002) and applying localized erosion coefficients (Hansen and Law, 2002).

Watershed Improvement

Stabilization and revegetation to native and desired non-native species to control erosion and implement other best management practices should be given high priority. Revegetation helps to stabilize slopes, reduce streambank erosion, and improve hydrologic function to promote infiltration and water storage into the soil. Soil productivity will be improved on about 800 acres per year of severely eroded lands (McKee and Law, 1985; McKee et. al., 1995).

Watershed improvement projects should focus on stabilization and revegetation of actively eroding gullies, galls (barrens), streambanks, old access and logging roads, log landings, illegal OHV trails, etc., particularly for watersheds and streams on South Carolina's 303(d) and 305(b) lists of impaired or concern streams included in the state's Clean Water Action Plan. Emphasis is given in Management Prescription 11 for all alternatives to protect and improve floodplains, wetlands, and riparian areas, as well as reduce impacts to species at risk. Protection of municipal water source areas, along with public health and safety, should also be priorities. Based on past Watershed Improvement Program accomplishments under the current forest plan, an average of about 150 acres of degraded/declining sites would be treated each year for alternatives E, F and I, with treatment varying from 125 acres/year in alternative G, 175 acres/year in alternatives A and D, to 250 acres/year in alternative B.

Elements of forest health can be correlated with soil quality with respect to occurrences of various diseases (e.g., littleleaf disease) and different pests (e.g., southern pine beetle). Poor soils and nutrient status affect tree growth and mortality. Deficient soils increase moisture and nutrient stress, which in turn increase susceptibility to insect and disease infestations (Briggs, 1993).

Restoration activities on some of the active gullies include reshaping to stable landforms. Practices such as bulldozing, KG blading, ripping and disking are sometimes used to treat these problem areas. A variety of stabilization and erosion control measures have been utilized (Hansen, 1991, 1995; Hansen and Law, 1993, 1996, 2000; Feltman et. al., 1996; Law et. al., 2000). Treatments intend to maintain long term cover for erosion control and soil building purposes. Short term treatment effects for gullies or other lands needing reshaping can produce soil losses of 4-to-50-plus tons/acre if not aggressively grassed and/or reforested. Erosion rates are lessened dramatically within just a few years, and some of the most successful treatments return to near natural levels in just 2-3 years. This program has produced long term recovery of extremely poor and barren sites to sites that grow fully stocked stands of 8-12 inch pine timber in 12-18 years. More recent treatment areas include native plants and trees as part of the desired results. Once restored, noticeable erosion is seldom evident on-site or in downstream areas. Atypical circumstances such as drought or intense rainfall are monitored and sites get added treatments including fertilizer, seed, and mulch, as needed, until recovery is achieved.

Estimated erosion effects by alternative for soil and water improvement activities must take into account the estimated erosion if treatments are not used, and the temporary-to-short term effects of treating the areas and result in long term improvements. Over the decade there is a net reduction in erosion from the activities.

Watershed Improvement Effects by Alternative

Alternative G has the least reduction in average erosion with -1,000 tons/year. Alternatives F, E, and I have -1,200 tons/year; Alternatives A and D have -1,400 tons/year; and B has -2,000 tons/year. Most of these activities are concentrated on the severely eroding lands in the piedmont, especially the Enoree Ranger District.

The sediment reduction benefits of the watershed improvement program on water resources were not included with other activities estimated at watershed scales in the water quality effects section.

Erosion

Soil erosion, the detachment and transport of individual soil particles by wind, water, and gravity, is a serious form of resource loss. It both reduces soil productivity and when delivered to streams as sediment, may lower the potential of the aquatic ecosystem including physical, biological, and chemical processes. Erosion is a natural element of the forest ecosystem initiated by disturbance factors such as wildfire, flood, wind, and other events.

A significant factor contributing to the amount of soil loss associated with surface erosion is the amount of bare soil created by an activity. With exposure comes the potential during rainfall and runoff events for soil dislodgement and movement. Other important factors in estimating the extent of soil erosion include soil texture, surface root densities, organic matter, infiltration rates, slope length, and slope (Dissmeyer and Foster, 1984). Revegetation of barren areas can reduce soil loss to negligible amounts between the third and fourth year (Dissmeyer and Stump, 1978). Erosion damage associated with vegetation management operations can be prevented by avoiding soil exposure and associated impacts or can be limited through erosion control measures. Limiting the area disturbed and exposed helps to control erosion. Litter, duff, and humus organic layers and the live fine root mat at-and-near the soil surface offer tremendous protection to the soil. Organic materials also promote maintenance of soil macropores, water absorption, and storage.

Forest management objectives for soil erosion include controlling soil loss rates and minimizing delivery of suspended and settleable solids to receiving streams. This helps protect aquatic habitats and sustain soil productivity. To help achieve this, a forestwide management standard calls for limiting aerial disturbance (bare soil) to less than 15% of any vegetation project area (10% within streamside management zones) and revegetating bare soil areas within the first growing season. Management standards require all newly constructed, reconstructed, and maintained roads, temporary roads, landings and skid roads, and other similar soil disturbing activities to implement best management practices

(BMPs) to control erosion. Waterbars, energy dissipaters below culvert outlets, and revegetation help meet this standard. In addition, soil ripping or subsoiling is utilized when compaction impedes vegetation and growth. Measures such as these limit productivity loss from activities by controlling runoff and erosion.

Soil Loss and Erosion Effects by Alternative

Based on the total erosion estimates for probable activities by alternative, Alternative G has the least erosion from national forest management activities with 30,100 tons/year. Alternative D had 49,000 tons/year; B, 50,800 tons/year; I, 51,600 tons/year; A, 53,800 tons/year; E, 57,200 tons/year, and F, 58,700 tons/year over the first decade. Addressed with other units and spread over the national forest, these values range from 53-to-103 tons/square mile/year (see Figure 3-1 below), which is equivalent to 0.08-to-0.16 tons/acre/year.

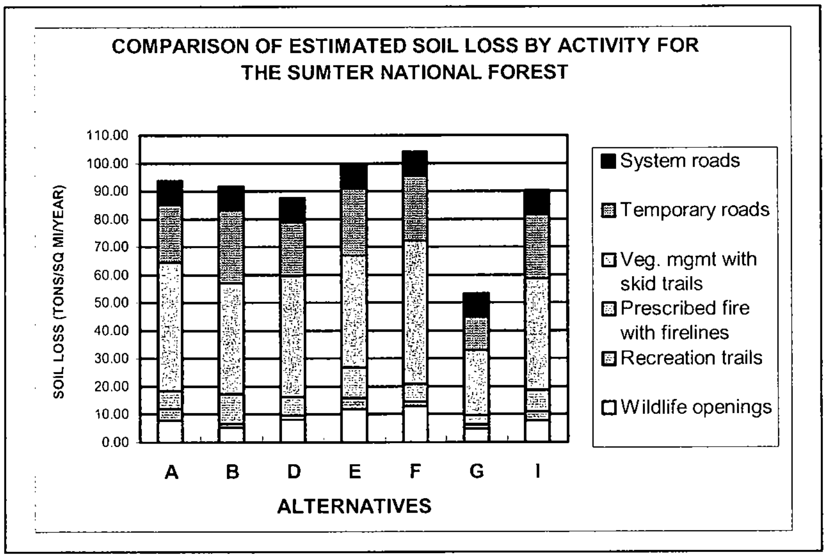


Figure 3-1. Soil Loss By Activity By Alternative

Soil displacement

The displacement of forest floor material can expose mineral soils, reduce nutrient supplies, lower available water, and increase soil densities, all of which are important to plant growth. Different soils have different sensitivities to displacement of surface layers due to variation in soil properties and qualities (e.g., topsoil depth, texture, structure, and stoniness) and other factors (e.g., slope, vegetative cover). The degree of displacement for a given activity often increases with slope until some point when other types of equipment and methods must be used to conduct the work. Soil loss can directly impair short- and long-term productivity because soil is a non-renewable resource. Root damage from skidding of logs and mechanical scattering may reduce tree vigor and resistance to disease and insect damage. Since fine root system mass concentrates in the upper foot of soil, it's imperative that soil displacement be minimized to protect long-term productivity. Ratings for soil displacement potential are based on the projected sum of acres in construction of fire lines, skid roads and landings, temporary roads, system roads, and areas involved in mechanical site preparation. Detrimental displacement is the removal of the forest floor and 50% of the topsoil or humus-enriched surface soil from an area of 100 square feet or more, which is at least 5 feet in width.

Soil Displacement Effects by Alternative

Soil displacement or movement potential for all alternatives is the same ranking as presented in the erosion section above – from the lowest displacement to highest are Alternatives G, D, B, I, A, E, and F over the first decade.
Note: This is the correct arrangement 102503.

Compaction

Soil compaction can alter soil structure, reducing the larger pores and pathways in the soil, decreasing macropore space and soil porosity (macropores are soil voids > 14 micrometers), and increasing soil density. Compaction is not typically noticeable on the surface and often is most evident 12-18 inches below the soil surface. Compaction reduces productivity by retarding root growth as well as air and water/nutrient movement, exchange, and availability in the soil. Compaction reduces the volume of soil available for tree roots, breaking pathways that supply transfer of water and nutrients, and impedes root penetration and growth. In some instances, compaction produces a temporary to semi-permanent restricted layer upon which water ponds during wet weather and which remains saturated for extended periods of time. In these instances, further reduction of air to roots and availability of nutrients can be restricted, especially if anaerobic conditions develop as they would under wetland conditions. These effects can cause excessive mortality or hinder the health of trees planted or seeded into disturbed sites. Fortunately, minor to moderate compaction will eventually breakup over a period of years as regrowth occurs.

Effects from compaction vary depending on the degree of change in soil density with depth, soil-site-relationships, and any mitigation completed. Surface soil recovery from compaction can be relatively rapid from the periodic freezing, thawing (frost heave) in the northern- and mid-latitudes with severe winters, but may take decades at greater depths even where freezing is much deeper. Because macropore space is reduced by compaction, many changes occur to soil function. The loss in soil macrospace makes soil infiltration slower; requires less water to saturate the soil; reduces water available for plants; delays soil drying due to fewer plants transpiring water and greater capillary forces holding water; and restricts air interface with soil particles. Since there are fewer freeze-thaw cycles, soil recovery from compaction in milder climates is less rapid and generally takes decades.

Fertilizer application can accelerate recovery rates of roots in compacted materials. Wetting and drying cycles, growth of plant roots, microorganisms, and soil fauna combine to ameliorate compaction over time. Soil ripping can reduce compaction and increase survival and growth of new trees in heavily compacted materials, such as temporary road surfaces. In severely compacted terrain, ripping in both directions can be done to further break up the soil surface. Planting trees into the rips can prove beneficial as they tend to collect water and dislodged soil, but care must be taken to avoid excessive air pockets in the soil rips by compacting sufficiently around the trees. Even the best tillage is unlikely to return compacted soils to their original condition and productive potential for many years.

The extent to which a forest soil is compacted depends on the kinds of equipment used, the soil type, and moisture level of the soil. Equipment types, weight, number of trips over the same area, and the weight of materials moved or skidded can be varied somewhat to reduce ground pressure, and to determine whether concentrated or dispersed activity will produce the best results. Slash, litter, duff, and humus layers each offer some weight absorption benefits that help limit load bearing effort onto the soil surface. Soil texture, structure, and moisture content combinations produce a wide variety of specific conditions where soil compaction is more likely if activities are conducted. Designating skid roads can reduce the area of compacted soil with reduced soil productivity. Mitigation efforts would concentrate on those specific areas impacted. In some instances, the amount of compacted area can be reduced by dispersing skidding routes to only one or two passes throughout the harvest area. This approach may work well where heavy slash and dry soils limit compaction. Low ground-pressure skidders are also available to help reduce compaction when soil or moisture conditions are not ideal, but the activity needs to be accomplished. Winching logs to skidders rather than driving to each log from a skid trail can reduce compaction. Feller bunchers often are used in flatter terrain, and these can help limit skidding effects by sawing or shearing small to moderate size trees and placing into skid lanes. Slash from the fallen trees and limbs are placed on the felling and skidding trails to reduce the ground exposure and compaction. There is little damage to the residual stand as the skidder damage to roots and tree rubbing is decreased. Some compaction from the feller buncher may occur, but this equipment tends to be lighter and more maneuverable.

For some excessively drained, sandy soils, there are positive aspects concerning a moderate degree of compaction. In addition, compaction on roads and trails provides greater shear strength and load carrying ability that supports safer, more efficient access and use of heavy equipment, including log landings, ATV trails, etc. Compaction also helps prevent puddling in that most of the water runs off and the greater shear stress prevents the soil particles from combining with the water particles. Compaction, thus, helps to stabilize road surfaces and equipment use areas. This also helps reduce long-term maintenance costs. A well-compacted travel surface with drainage controls and gravel treatment (as needed) provides an excellent running/operating surface while reducing erosion, stream sedimentation, and dust abatement that may adversely affect air quality as well as adjacent flora and fauna. With heavy equipment, the travel surface may need a coarse base of cobbles and gravel for best support.

Compaction Effects by Alternative

Soil compaction commonly occurs with operation of equipment as well as dispersed foot traffic by humans and animals. Sometimes soils are compacted deliberately for good purposes such as in road construction. However, for purposes of establishment, growth, and health of forest and other desired plants, compaction can be detrimental, especially when soil densities exceed the growth-limiting threshold for root penetration. Compaction is avoided except for areas needing compaction such as roads and trails. Potential compaction effects were the greatest for management activities using heavy equipment, especially under moist soil conditions. However, most of the affected acres in all alternatives include intentionally compacted areas such as temporary roads, log landings/storage areas, primary skid roads, trails, recurrent use fire lines, etc. These areas are generally well dispersed and limited in extent; however, without mitigation they often produce a severe reduction in long-term plant growth and are irretrievable allocations of resources that are, more or less, dedicated to these uses, unless intentionally reversed by road decommissioning activities.

Soil compaction for all alternatives was estimated to be the same ranking as presented in the erosion section above, from the lowest displacement to highest are: Alternatives G, D, B, I, A, E, and F over the first decade.

Slope Stability

Slope stability problems are confined to primarily colluvial soils such as the Brevard soil series in the mountains. Slope disturbances produced by construction of roads, skid roads, and log landings, etc., can potentially initiate or accelerate existing soil mass movement or areas prone to instability by undercutting, hydrologically loading a slope, or disrupting established drainage patterns. Internal soil strength and external factors (e.g., root systems, ground water, bedrock type, and subsurface flow pattern) are important aspects of slope stability. Visible indicators of these conditions include misshapen trees, jackstrawed or leaning trees, cracks in the soil with exposed subsurface roots, and a series of steep and flat areas or rotational slumps across these areas (Hansen and Law, 1996). Road or trail building activities in these soils should consult soil, geology, engineering and/or hydrology specialists to evaluate.

Slope stability involves a complex interaction of soil shear strength, soil depth, slope gradient, groundwater rise – as related to precipitation – and tree root strength. Decisions regarding slope stability cannot be made without risk. All sloping soils seek to achieve a flat gradient over time, as influenced by erosion and landslide events. Assessments of stability and risk/hazards should be correlated with geologic formations/bedrock types frequently associated with slope failures (e.g., characteristics such as competency or rock strength, lithologic discontinuities, hydrogeological conditions/hydraulic conductivity and porosity, weathering, clay mineralogy, and strike and dip of beds). Risk ratings of "severe or moderate" do not necessarily indicate an imminent or incipient failure. Such ratings mean only that slope adjustments are likely, especially if slope or hydrological modifications associated with road or trail cutting, filling, and compaction on these soils alter the groundwater flow within the area or the slope support from excavating and removing materials. In some instances, where crossing these areas are critical, toe slopes can be supported with riprap, wall buttress, or similar method, and subsurface drainage can be brought to the surface by installing perforated drains into the slope.

Slope Stability Effects by Alternative

The potential risk for conducting activities on unstable slopes is low for each alternative because of the limited terrain in this hazard (2,250 acres of Brevard soil series in the mountains). Other small areas with slope stability problems less than 5 acres in size exist, but were not mapped on soil inventories. Where found, they are typically on localized areas of slope changes near streams, at the base of slopes or certain lithologic contact zones.

Soil Productivity

Extensive areas of the Sumter National Forest were severely impacted by past cultivation practices. The resultant severe erosion remained unchecked for extended periods of time and left considerable areas denuded, with deficiencies in nutrients, water retention, and ability to grow plants. Efforts have been underway for decades to treat these declining watershed lands, reducing areas of gullies and other severe erosion and regaining the growth potential on nutrient deficient lands though selective fertilization. Continued needs include the maintenance of plant cover, increasing root density, organic matter, and depth of the surface soil. However, rebuilding the soil surface may take centuries for full recovery to develop.

Activities that may substantially and/or permanently impair productivity of the land include road and trail building, cultivated openings, utility corridors, campgrounds, parking lots, etc. Activities that impact productivity can do so in a variety of ways when they alter and degrade soil quality or impair the soil's capacity to perform functions needed in the sustaining of plant and animal productivity. Usually when productivity losses are discussed, these effects remain as long as the facility is used. However, these effects can be reversed to some extent with treatment and sufficient time. There are irretriveable commitments of resources for these areas, but though severely altered, they are not irreversible commitments if sufficient resources and time are allocated.

Productivity Effects by Alternative

Productivity effects estimates can be very complex. Recognizing that erosion is but one element of productivity to consider, total erosion estimates are still the best indicator of overall productivity changes for the alternatives. Based on the total erosion estimates for probable activities by alternative, Alternative G has the least erosion from national forest management activities with 30,100 tons/year. Alternative D had 49,000 tons/year; B, 50,800 tons/year; I, 51,600 tons/year; A, 53,800 tons/year; E, 57,200 tons/year, and F, 58,700 tons/year over the first decade. Addressed with other units and spread over the national forest, these values range from 53-to-103 tons/square mile/year, which is equivalent to 0.08-to-0.16 tons/acre/year.

In addition, fertilization of impoverished lands of 70 site index or less is used to improve soil productivity. In comparing the alternatives, the least number of acres would be improved in alternative G at 500 acres/year (A/Y), and most in alternative F at 1,000 A/Y. Estimates of treatments for other alternatives include I, 700 A/Y; D, 720 A/Y; E, 750 A/Y; B, 780 A/Y; A, 820 A/Y.

Watershed improvements to gullied and severely eroding lands mentioned earlier also provide marked increases in productivity and the ability of the soil to support healthy plants, maintain soil cover and increase organic content. Alternative G would treat 125 acres/year, 150 acres/year for alternatives E, F and I, 175 acres/year in alternatives A and D, and 250 acres/year in alternative B.

Cumulative Effects

Soil Productivity

Compaction, displacement, erosion, slope stability, and nutrient status all influence soil productivity. For this reason, assessing overall soil productivity was selected as the best indicator of cumulative effects. Elements of the individual components may be addressed, but this is an overall assessment of the cumulative impacts to soil productivity from the forest plan revision alternatives. Most soil effects occur on-site or on areas close-by. Therefore, these effects will concentrate on what is happening to the soils on the national forest and immediately adjacent areas, and not be discussed at landscape or watershed scales which are being handled in the riparian, water, and watershed discussions.

The forest management activities with the greatest long-term potential impact to soils are associated with construction of roads, log landings, primary skid roads, timber harvest on steep slopes using conventional equipment, and actively cultivated openings, especially those that exceed 3-4% slope. Heavily compacted areas such as roads have permanent losses in productivity unless efforts are undertaken to close, rip the road surface, and use erosion control and revegetation methods to mitigate the effects, which will occur with temporary roads with treatments, and with time.

Temporary productivity losses are dispersed across timber harvests and other activities that use heavy equipment on the landscape. These losses reduce with time, revegetation and mitigation measures such as fertilization, seed, and mulch. Mechanical site preparation and frequent or hot prescribed burns can also reduce soil productivity over time, especially when associated with steep slopes or severely eroded soils. Activities that are combined with others, especially when conducted frequently, need careful evaluation and attention to sensitive soil types. These complex combinations can reduce productivity and may go unnoticed unless specifically evaluated. Potential productivity losses can normally be mitigated or minimized if calculations of erosion or nutrient loss indicate that further testing is necessary. Soil and vegetation observation and physical and/or chemical tests are sometimes used to verify specific problems. Besides mitigation measures to designated areas affected, natural responses such as the establishment of native grasses, trees and nitrogen fixing plants help to reduce these effects.

Effects from these activities vary with soils, but soil loss and erosion are the basis of evaluating soil productivity losses. The tolerable forest soil losses vary somewhat by soil type and slope conditions (Region 8, 1982). For most combinations of activities on the highly productive flat lands under 5% slope, erosion is minor and productivity losses are considerably less than forest and regional standards. For most of the low to moderate slopes with average productivity, no more than 85 tons/acre of soil loss should occur over a 100-year period. The Regional Guide allows for short-term loss up to 10% of this total or 8.5 tons/acre/year. Long-term combinations of treatments over a planning horizon should not exceed 43 tons in 50 years without mitigation or other changes to limit these losses. These estimates are based on the average and better piedmont and mountain soils. Poor or heavily eroded sites can loose only about one-half of these amounts and maintain productivity. Specific mitigation measures can be developed to limit or offset the productivity losses. Maintenance of native plant cover provides a permanent deterrent to erosion and productivity losses. Fertilization can offset nutrient losses or increase in cycling and mobility rates from soil mixing and/or exposure. Other mitigations that lower and offset erosion rates increase permanent cover, limit soil exposure, reduce soil disturbance, and/or increase root density and organic content in surface soils. Efforts to lower erosion relative to the erosion factors associated with the Universal Soil Loss Equation, typically target actions that avoid or mitigate concentrating flow (i.e., altering slope, slope length); limit disturbance and maintain a high degree of soil cover with leaves, organic surface and root density (i.e., provide low C factor); and encourage soil development (i.e., reduce soil K factor).

In the short term, the alternatives disturbing the greater area in compacted surfaces and those that rely on utilizing the steeper slopes associated with that activity will potentially generate the larger short-term reduction in productivity from excessive soil loss and disruption of infiltration and nutrient cycling within the soil. In ascending order from least to greatest potential for productivity losses within the first decade, would be Alternatives G, D, B, I, A, E, and F over the first decade. Soil and water improvement actions that benefit watersheds are lowest to highest in Alternatives G, E, I, D, A, F, and B over the first decade. However, with implementation of prescribed management measures (i.e., revegetation of bare soil areas, maintenance of native plant understories, thinning, partial cutting, stage regeneration, contour tillage, no-tillage, reducing frequency of activity, altering season of treatment, etc.), the short- and long-term cumulative effects from erosion would be for most activities, within tolerable soil loss rates that are needed to sustain productivity.

In regards to compaction, much of the affected area occurs in areas allocated or otherwise designated for future use (e.g., roads, trails, log landings, primary bladed skid roads, fire lines for frequent burning cycles, high use recreation sites) in support of long-term management objectives (e.g., timber harvest, wildlife habitat improvement, recreation). Compaction above the projected growth-limiting bulk density for a particular soil (1) which extends more than 4 inches in depth; (2) where there is a 20% or greater reduction in macro-pore space; or (3) where there is a 15% increase in bulk density, residual long-term effects will likely be present in the foreseeable future. On compacted sites mitigated by mechanically ripping or subsoiling compacted soils, fertilizing and revegetating them can help to reverse this effect as plant roots help break up compacted soil with time.

Compaction often concentrates at depths below the surface of 12-to-18 inches, so disking is often not sufficient to mitigate the effects of compaction. Indentations in the soil surface are not necessarily a sign of compaction; they are more typically a sign of rutting or displacement that occurs in wet soils. Rocky or coarse sandy soils show limited effects from compaction. Clay soils tend to hold water and displace rather than compact. However, the silt dominated soils tend to provide the most problem. Compaction cannot be seen from the surface, and some soils are more of a hazard for compacting than others. Severe compaction should be ripped at depths of 18-24 inches in one or both directions to breakup the compacted soil layers. Special ripping teeth are designed and spaced specifically to improve breakup of compacted layers. Ripping should not be used under wet or moist soil conditions, as these soils deform rather than rip. Ripping on the contour is recommended when used on sloping terrain, and the practice may also be used to help break up problem soils where the existing fragipan or hard pan is near the surface on relatively flat to moderate slopes, affecting root and water penetration, plant health and surface erosion. Where affected areas aren't adequately restored following compaction impact, soil density will slowly revert to normal levels based on the frequency of freeze-thaw cycles, plant root penetration, soil microorganisms, earthworms, moles, etc. It would not be unusual to expect some effects of the soil compaction to linger for decades if treatments are not employed to break up the compaction.

Cumulatively, environmental consequences to soils from past, present, and foreseeable actions are minimized through careful planning, design, implementation, and monitoring. Most adverse impacts will be low-to-moderate. Activities that alone or combined with other actions tend to produce a high level of impact are restricted to flatter slopes and soils where the degree and extent of impact is lessened to acceptable levels. Therefore, long-term soil productivity losses will produce irreversible effects on only permanent roads, where mitigation over time is not expected. Other combinations of activities that have the potential for long-term productivity loss will be evaluated and mitigated as needed.

Watersheds, Streams, and Water Resources

Affected Environment

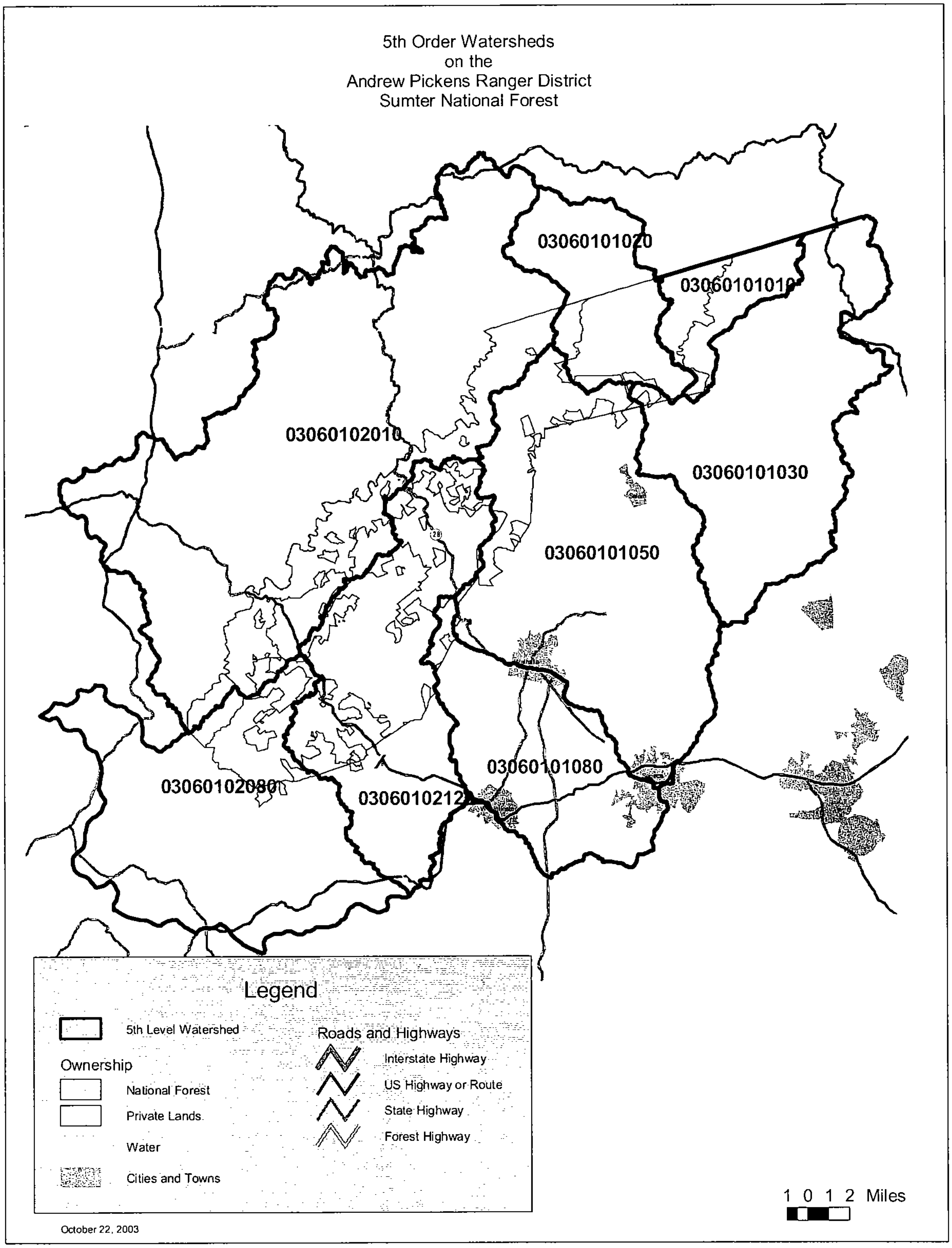
For the most part, watershed discussion at this coarse forest plan scale will be about the 28 hydrologic units (HUs) called fifth level watersheds that intersect the Sumter National Forest. Each watershed is identified and typically ranges from 40,000 to 250,000 acres in size and has a numeric code. The term watershed is sometimes also used generically to refer to activities that relate to soil and water improvement or to refer to a hydrologic unit of no specific size. When possible, the appropriate hydrologic unit size will be used such as basins (third level HUs), subbasins (fourth level HUs), watersheds, subwatersheds (sixth level HUs), drainages (seventh level HUs), subdrainages (eighth level HUs), etc., to address small to moderate-scale hydrologic units. Area and project level analysis may include or reference small to moderate scale HUs, but generally concentrate on large scale to site specific conditions. The fourth and third order tributaries referred to as "*Drainage Basin Response Units*" (Patterson, 1981) in the 1985 plan generally coincide with the eighth and ninth level HUs and typically contain perennial flow (Hansen, 2001). The branching of the stream network extends to second and first order streams, and sometimes further densifies in severely eroded areas. The headward extent of stream systems is estimated by using the USGS contour map crenulations, but field verification is needed to determine the stream types and extent (Hansen, 2001, Meyer et. al., 2003).

The lands of the Sumter National Forest were acquired primarily under direction contained in the Weeks Law of 1911. This law instituted improvement of impaired lands to provide sustained forest and water resources for the Nation. Most were "The Lands that Nobody Wanted" (Shands and Healy, 1977). Severe surface erosion and formation of gullies and galled barrens affected much of the landscape (Schumm et. al., 1984). Much has been accomplished over the last 70 years to improve watershed conditions on the Sumter National Forest.

Improvements to watershed conditions have occurred on both national forest lands and, to a lesser extent, on private lands. Many of the once actively eroding gullies, galls, and roads on the national forest have been stabilized and/or restored to normal function (Hansen, 1991, 1995; Hansen and Law, 1996; Law et. al., 2000). On private lands, major land-use shifts from intensive cropping to forest and pasture uses have improved the soil management and hydrologic function of the landscape. Increased attention to BMPs and conservation practices in South Carolina are common (Hook et. al., 1991; Adams and Hook, 1993; Adams, 1994, 1996; Jones, 2000). However, some of the residual effects of past actions are hard to remove totally.

Alluvial valleys below extensively eroded lands in the piedmont were filled with sediments, and many streams are still adjusting (Happ, 1945, Trimble, 1974, Hansen, 1991, Alexander, 1993). Rosgen G type gully channels are deeply entrenched into the alluvial sediments (such as Isaacs Creek, Enoree Ranger District (RD), Figure 3-2) (Rosgen, 1996). Deep entrenchment causes reduction in flooding to alluvial terraces. Many of these terraces remain as riparian areas due to the abundant, well dispersed rainfall, extensive network of streams and colluvial slope interface that contribute surface and subsurface water to maintain soil moisture and riparian species. Channel scouring and widening processes continue as some channels evolve to either reach their original base level or approach stability at a new level. As the valley gully channels widen with associated instability of the streambanks, entrenched Rosgen F type channels emerge with high width to depth ratio character (such as Pattersons Creek, Enoree RD, Figure 3-2). When the lateral changes subside and streambanks stabilize, internal adjustments of channels may rebuild a small floodplain within the F terrace confinement into Rosgen C type channels (such as lower Pattersons Creek, Enoree RD). Urban, development and other activity within some drainages are showing signs of channel aggradation and increased flooding of riparian areas in some valleys, possibly a result of renewed sources of sediment, increased flows and/or adjustments due to legacy sediments. Examples of this include Tinkers, Headleys and Indian Creeks, Enoree RD (Hansen et. al, 2003).

Figure 3-2. Small perennial streams Isaacs Creek (left) and Pattersons Creek (right) show roots and trees in their entrenched channels that were once buried by sediments from severely eroding hillslopes and gullied terrain. They are indicators of the modern valley elevation that was buried in the late 1800s to early 1900s. Isaacs Creek is widening, but remains a Rosgen G5 (gully) type channel with low width to depth ratio and dominated by sand size particles (Wolman, 1954), while Pattersons Creek is a Rosgen F5 channel with relatively high width to depth ratio and dominated by sand size particles.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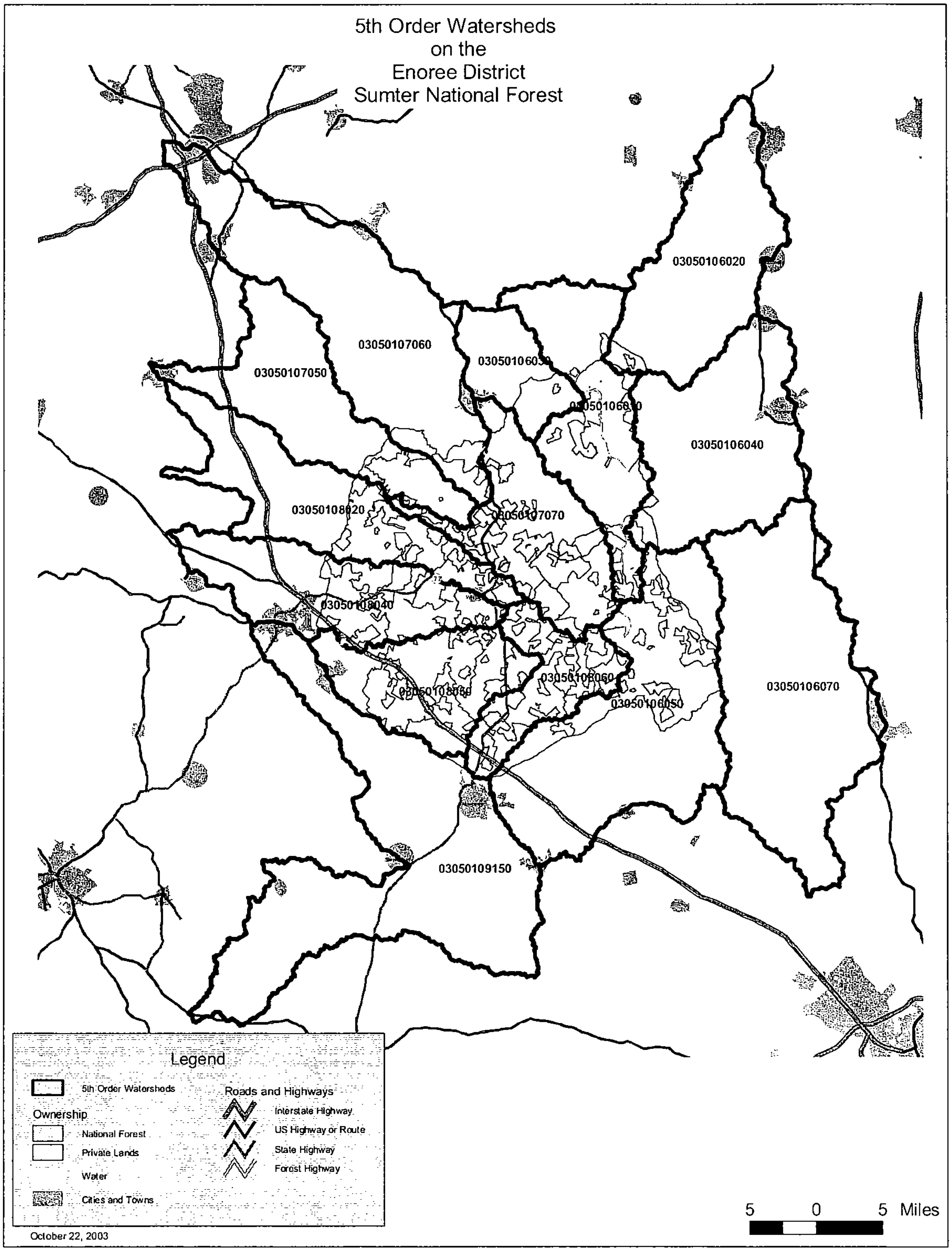
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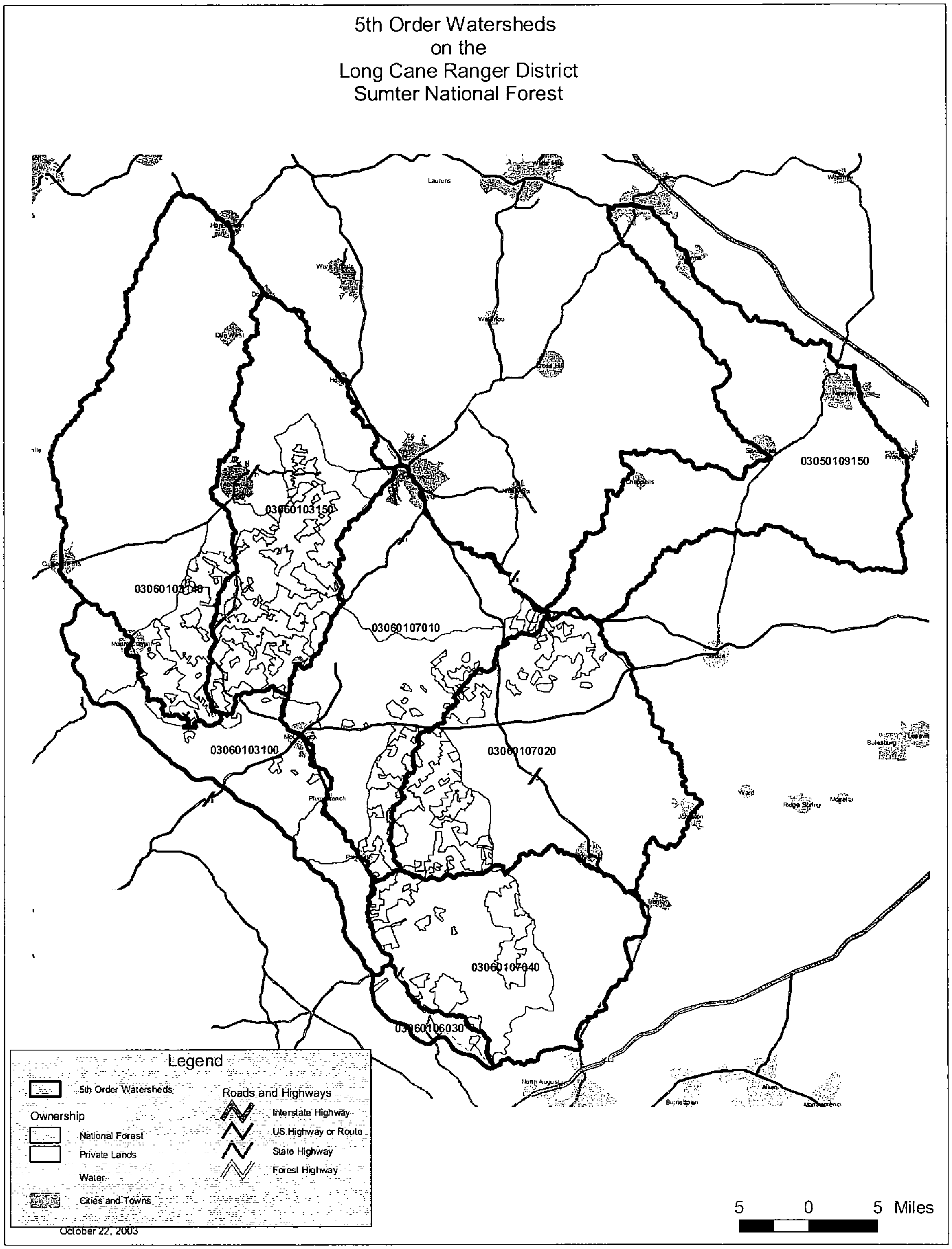

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Roads and Highways
Interstate Highway
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October 22, 2003

Rainfall, Streamflow, and Water Yield

Average annual precipitation on the Sumter National Forest varies from about 45 inches in the piedmont to 70 inches in the mountains. Rainfall is well dispersed throughout normal years which helps to maintain flow in some small second order streams and most that are third order and larger (Hansen, 2001). Rainfall frequency data indicate that rainfall intensities in the southeastern United States are much higher than average and among the highest in the nation (Hershfield, 1962, NOAA, 2003). Average annual water yield on the forest ranges from about 10 to 20 inches from the piedmont with the southern portions of the Long Cane Ranger District the lowest and the northern portion of the Enoree Ranger District the highest (USGS). Water yield in the mountains ranges from about 30-50 inches with lower amounts in the southwest at lower elevations and higher amounts in the northeast at higher elevations (USGS). Yields vary annually based on storm events, climate, and water uses within watersheds. Severe storm events are infrequent and are sometimes generated at localized drainage scales with summer thunderstorms. At broader scales, inland storms that develop from hurricanes and tropical depressions can interject copious amounts of moisture in the air, which may release moisture as it rises and cools in passing over the land, or as the warm moist air is pushed upward by cool passing weather fronts. Average annual water yield for SNF is approximately 760,000 acre-feet or 1.03 billion tons of water.

Streamflows are typically lowest during summer months into August or September and highest during winter months in December through March. Weekly minimum flows for 2 year return periods for Long Cane Ranger District streams are typically 0.1 to 0.2 cubic feet per second per square mile (CSM), with Enoree Ranger District ranging from 0.1 to 0.26 CSM and Andrew Pickens Ranger District from 0.5 to 2.0 CSM (Zalants, 1991). Weekly low flows that return on an average of 10-year intervals are about 40-70% of these values. Smaller drainages typically have a higher minimum flow rate per unit area than larger drainages. Some reasons for this lower flow per unit area for larger drainages are: 1) more water uses such as irrigation can be found along larger drainages; 2) added evaporation and transpiration by riparian plants; and 3) coarse, deep substrates may contain subsurface flows that are not observed or measured during low flow periods. These low – or in some instances interrupted – flows may give a competitive edge to specific types of aquatic organisms that are able to survive or live within the channel substrate, or take advantage of interrupted pool habitat maintained by subsurface flow. Extreme low flows on many streams occurred during the extended drought from 1996-2001 that ended in above normal rainfall during the spring and summer of 2002.

The magnitude and frequency of rural floods in South Carolina can be estimated using standard hydrological techniques (Guimaraes and Bohman, 1989, Feaster and Tasker, 1999). These estimates can be refined when needed by selecting individual station data for the area of concern (Hansen, 1989). Flow duration curves can be developed for the long-term stations that can be used to predict flow duration on adjacent areas. South Carolina normally benefits from rainfall throughout the year, so the extent of perennial and intermittent streams is much greater than many areas of the United States. In addition, the extent is also well beyond the blue lined streams identified on the 1:24,000 scale topographic maps published by the US Geologic Survey (Hansen, 2001, Meyer et. al., 2003).

Groundwater

Groundwater occurs locally as no major aquifers exist in the mountains or the piedmont. Surface water is the main supply of water for consumptive and non-consumptive use to communities and local public water supplies, however individual wells often supply enough water for rural private home use. Use of groundwater on the forest is limited to primarily administrative sites including hunt camps and campgrounds. Currently, there are wells at 28 administrative and recreation sites with 13 sealed wells no longer used and abandoned, and 1 domestic spring at Moody Springs picnic area on the Andrew Pickens RD. In an effort to limit private uses affecting the National Forest, there are no domestic wells or springs currently under special use permit.

Water Rights and Uses

South Carolina water right law is based in the riparian doctrine, which allowed reasonable water use as part of landownership, as long as that use did not infringe upon other property owners and their use. Information concerning amounts and types of water uses compiled by the South Carolina Department of Health and Environmental Control (1995) is included in the cumulative effects discussion.

Non-consumptive uses of surface water resources comprise most of the on-forest demand for water. This use includes recreational activities (such as swimming, fishing, and boating) on streams, lakes, and reservoirs and power generation from reservoirs. Important non-consumptive uses include the flows needed to maintain aquatic habitats and for channel maintenance. Maintenance of flow for scenic waterfalls, river floaters, swimmers, hikers, and campers is important to many mountain as well as piedmont visitors. Waterfall spray zones provide some special habitat needs.

Consumptive water uses on forest (such as industrial or municipal withdrawals) are negligible. Administrative uses for water include needs for fire suppression and control, water to maintain plants during periods of drought, road needs for dust abatement and to meet compaction specifications, and small impoundments or water retention areas for recreation, fishery, aquatic and wildlife uses. There are several special use authorizations for water transmission including water transmission pipelines for the SC Parks, Recreation and Tourism, City of Union, Newberry County, Bradley Community Association, a road watering company, and an individual. Three special use permits are also noted in the mountains for small reservoirs with portions within or structures such as spillways on the National Forest. In the mountains, Westminster, South Carolina, obtains its municipal water source a short distance below the Sumter National Forest boundary in the Chauga River, with a backup source in Ramsey Creek. Watersheds north of Coneross Creek contribute to Lake Keowee, which is the municipal water source for Greenville and Seneca, SC and the Oconee Nuclear station. The Walhalla Fish Hatchery returns most of the water diverted from Indian Camp Fork or East Fork Chattooga River for temporary uses within their trout and fish breeding tanks. Several domestic water uses are provided from springs or small streams to private individuals as requested under special use permit.

Municipal water uses in the vicinity of the Long Cane Ranger District include McCormick, SC from Lake Thurmond and North Augusta, SC and Edgefield County from the Savannah River. Municipal uses adjacent to the Enoree Ranger District include Whitmire, SC with source in the Enoree River with Duncan Creek as a backup source; Union, SC, Lockhart Mills and Carlisle Cone Mills are supplied by the Broad River. Columbia, SC is also supplied by the Broad River a substantial distance downstream.

There are about 15 small ponds and reservoirs averaging about 5-10 acres in size within National Forest boundaries. Most are older structures that have poorly maintained dams that will need heavy maintenance practices to remove trees and repair damage that has occurred over extended periods of time. There are also many privately owned ponds on adjacent lands that have some influence on forest streams. The dams that are owned and managed by the National Forest were constructed or obtained through acquisition or, land exchange and used for a variety of recreation, wildlife and fishery uses. Hydrologic modifications have a variety of effects on water quality, flow regime, and aquatic habitats (Glasser, 2000). Through cooperative agreements, some of the adjacent small privately owned dams in the mountains have been retrofitted for bottom releases to reduce the effects of surface warm water discharges on trout and other aquatic species in the summer months. There are several small hydrologic control dikes within major river floodplains that were developed specifically for waterfowl habitat. Water sources may include tributary streams, water diversion with control structures, and unregulated sources from river overflow channels, sloughs, tributaries and groundwater seepage. Some have employed intermittent pumping of water to or from nearby streams and rivers to try to better control water depths within the structures to meet desired water control needs. Where these activities concentrate attract abnormal wildlife populations, excessive levels of water pollutants may accumulate. Mitigation in design and discharge may be needed to limit contamination from pollutants such as nutrients, fecal coliform, pathogenic organisms (e.g., *Escherichia coli*, *Cryposporidium* spp., *Giardia* spp.) (Nadareski, 2000; Scatena, 2000; Stern, 2000; Tiedemann, 2000). Discharge permits are obtained when required. Natural influences to channel hydrology and chemistry are increasing from the impoundment and diversion expansion of the beaver throughout much of the stream network. Beavers have expanded flooding of local valley and channel areas, causing changes in riparian vegetation, streambank stability and water quality. Road culverts are sometimes plugged by their handiwork. Their dams are damaged from time to time by flood events. Changes in stream temperature, turbidity, sediment, fecal coliform and other contaminants may occur due to the changes in hydrology and biologic uses.

An increase in the public demand for water is anticipated in the future. The high quality waters from the national forests in general are expected to be in increasing demand to meet local community and recreational needs for both consumptive and non-consumptive water uses. The effects, both positive and negative, can be very complex associated with these added demands for water development and use. South Carolina has recognized the potential need for a better water management system to keep pace with this emerging issue. Proposals to alter streams and riparian areas affecting the National Forest require close scrutiny to address public and environmental concerns.

Streams

Perennial stream densities are higher in the humid southeast, especially in the mountains, than many other areas of the Nation. Using the Chattooga River watershed as an example, stream density by type was estimated at 2.9 miles of perennial, 1.7 miles intermittent, and 5.6 miles ephemeral streams per square mile (Hansen, 2001). Stream densities may vary somewhat with the other watersheds in the mountains and piedmont. The piedmont has gullied and galled lands with additional drainage density that cannot be picked up at 1:24,000 scale maps and this level of detail cannot be included in these estimates. The drainage density of the piedmont is similar to the mountains, but the perennial stream extent is likely somewhat less in the piedmont due to lower rainfall rates, with some resultant increases in the amount of intermittent or ephemeral streams.

Rosgen stream types common to the mountains are B, A, and G in hillslope and higher gradient valley terrain, with F, and C types in low gradient valleys (Rosgen, 1996). Dominant stream channel materials are typically sands, gravels, cobbles, and less common are boulder or bedrock substrate. Valley types are somewhat confined and develop from steep to moderately sloping dissected terrain with alluvial, colluvial, fluvial, and residual soils. Some streams have controls from past geologic faulting and folding of predominantly metasedimentary materials. In a few instances, substantial shear fault lineaments such as the Brevard Fault align and confine portions of Brasstown Creek and the Chauga River. Years ago, log splash dams were used on the West Fork Chattooga, Chattooga and perhaps a few other rivers to move logs for processing at the mill. When the dams were broken, the water volume coursed through the channels and moved the logs like a huge water sluice to the mill or to a stream access point, causing extensive channel and bank erosion, sedimentation, and river alignment adjustments. Some channel obstructions were removed with dynamite to prevent log hangups.

Piedmont stream types are commonly Rosgen G and F stream types with infrequent B and A types in hillslope dominated terrain. Streams in broader valley bottoms are often Rosgen F or C types, occasionally G, and less commonly E and D types with dominate substrate materials being commonly sands, occasionally gravels, and infrequently, cobbles or bedrock. Alluvial valley types are low to moderately sloping with moderate to high hillslope drainage densities. A few instances of stream segment alignment due to geologic faulting are present, though much less frequent and for shorter distances than in the mountains. Saprolite parent materials are a result of the deeply weathered geology in the warm, humid subtropical climate, making thesoil C horizon and residual geologic materials more erodible. Past farming and development activities have produced extensive deposits of alluvial material in valleys from severe surface, hillslope, and gully erosion (Happ, 1945, Trimble, 1974, Schumm et. al., 1984, Hansen, 1991, Alexander, 1997). Surface erosion was a dominant feature across the landscape, averaging nearly a foot of soil loss with modern valley deposits about four to ten feet thick that aggraded streams, buried valleys and increased flooding. However, conversion of substantial areas of eroding farmlands to forests tended to reverse the trends that overwhelmed streams with sediments, allowing the processes of stream channel incision into the recently deposited alluvial and fluvial soils.

Channels continue to adjust in the gullied headwaters and alluvial valleys. Episodes of entrenchment, bankfailure, widening and deposition continue to actively modify stream sections through time. Improvement is occurring, but equilibrium and stability are slow in coming. Channel entrenchment, low to high width-to-depth ratios, and unstable streambanks are common features across much of the piedmont landscape, especially on the Enoree RD.

Due to both natural and human efforts in reforestation, revegetation, and stabilization of the land over the last 70 years, many drainages have improved soil infiltration, which has helped to lower runoff to more normal levels. Conversion of hardwood dominated terrain to agricultural uses in the 19^{th} and early 20^{th} centuries increased water yield and stormflow, but likely reduced low flows. During recovery of formerly agricultural land to pine dominated forests on the SNF, lower water yields and stormflows resulted from a combination of the increased infiltration and evapotranspiration. Reforestation and soil building have improved watershed condition. Streamflow and runoff coefficients are moderated and closer to normal levels found with stable forests. Conversion of pine forest conditions back to hardwoods or native pine species, adding increased areas in savannah, woodland and wildlife opening management will increase water yields to some degree, causing localized channel adjustments within areas of concentrated activity. These changes are moderated by protecting the soil surface, and allowing controlled and relatively slow changes to drainages and watersheds over time.

Watersheds

On a regional scale, the Ranger Districts of the Sumter National Forest appear as three dots within the South Atlantic-Gulf Hydrologic Region. The Enoree District is within the Santee River Basin, connected through the Broad and Congaree Rivers, and includes the Lower Broad River, Enoree River, and Tyger River subbasins, intersecting 14 watersheds. The Andrew Pickens and Long Cane Districts are within the Savannah River Basin that includes areas within the Tugaloo River, Seneca River, Little River, Stephens Creek, and Lower Savannah subbasins, intersecting about seven watersheds on each district. The 28 fifth level hydrologic unit code (HUC) watersheds that contain some national forest lands in South Carolina vary in size from 21 to 335 square miles. Each of the hydrologic units is defined and numbered in the state HUC maps, which are being adjusted to meet new national criteria.

Many of the specific attributes of the watersheds were summarized in the Broad Scale Watershed Analysis for the Sumter National Forest (Hansen et. al., 1999, 2002). See Appendix M for a summary of the information collected during this analysis. More detailed information on the USDA Forest Service watershed analysis process in Region 8 can be found in Watershed Analysis – A Proposed Process for Forest Planning (Holcomb et. al., 1999). The Sumter watershed analysis included some information from Watershed Water Quality Assessments of Savannah and Broad River Basins by the South Carolina Department of Health and Environmental Control (DHEC Technical Reports 002-93 and 001-98). **The watershed analysis process for the SA forests focused in on sedimentation, addressed in more detail within the process records (Clingenpeel, 2003a, 2003b, Hansen and Law, 2003).** Most of the watersheds contain only a minor portion of National Forest System lands.

Pure or classic watersheds are hydrologically self-contained. Those classic watersheds with 15% or more national forest lands include Chattooga River, Chauga River, Indian Creek, Duncan Creek, Long Cane Creek and Turkey Creek (within Stevens Creek subbasin). After all classic watersheds are identified across a landscape, there are leftover portions or remnants of the landscape that typically are made up of smaller drainages within intermediate or lower sections along a river. These areas are called composite or remnant watersheds in that they are not self-contained hydrologically as one or more watersheds contribute to them. These remnant watersheds were given unofficial names to help describe their relative location to each other within the national forest. Those residual watersheds with over 15% national forest ownership include Lower Enoree River, Middle and Lower Tyger River, and Lower Savannah River. Subbasins are fourth level HUCs representing the next smaller scale hydrologic units and typically contain 4 to 6 watershed units. At larger scales, the fifth level watersheds are also divided into smaller hydrologic units called sixth level subwatersheds. Finer divisions are possible to drainage, subdrainage, and tributary units. For more detailed areawide or project level work, these are mapped in detail within the SNF boundary based on prior stream ordering and drainage analysis (Patterson, 1981). In a few instances, this mapping of fine hydrologic units has extended to full watersheds with substantial national forest presence (Hansen, 2001, Hansen et. al., 2003).

Watersheds were selected as an analysis unit because much of what is known about forest ecosystems was derived through the study of small hydrologic units called drainages or catchments. It is interesting to note that some of the ancient cultures studied water movement, streams, and watersheds to help solve problems of their day. Water was recognized as a key element in daily life, providing drinking fluids, transportation, food, and recreation. The study of hydrologic information is no less important today. Watersheds not only combine many elements of the hydrologic cycle, but many aspects of nutrient and energy cycles are linked to hydrologic functions. Not surprisingly, water pollutants are also heavily correlated with water cycles.

The early study of hydrologic phenomena was based on careful selection and instrumentation of study drainages (American Geophysical Union, 1965). Watershed experimentation began in forest and pasture land in Switzerland (Engler, 1919) and in the United States at Wagon Wheel Gap, Colorado (Bates and Henry, 1928). For extended time periods, hydrologic studies collected information on responses to environmental conditions and forest management (Hibbert ,1965; Bormann and Likens, 1969; Hewlett and Pienaar, 1973). Wilm (1944), Ward (1971), Toebes and Ourgvaev (1970), and others provided reviews of watershed experimentation concepts, techniques, and analyses. Some of this information will be considered as the reference watershed conditions are characterized, studied, and compared to managed watersheds.

Discussions about hydrologic units are more defined today because advances have been made in delineating and describing the hierarchy (NRCS, 2003). Once learned, this helps to reduce confusion and communication problems dealing with hydrologic scale. The Hydrologic Unit Code was developed nationally for mapping and differentiating hydrologic units by region, subregion, basin, subbasin, watershed, subwatershed, and if necessary, finer scales. Each level has two digits that describe their relative position in the hierarchy, with watersheds being the fifth level with ten digits. The fifth level hydrologic units or watersheds are a primary communication and analysis tool that is currently being used for analysis of roads and watershed conditions.

Water Quality

All major streams and many important tributaries on the forest are classified by the State of South Carolina *Stream Classifications for the State of South Carolina*, South Carolina Department of Health and Environmental Control, 2002. The stream classifications from most to least restrictive include categories of Outstanding National Resource Waters (ONRW); Outstanding Resource Waters (ORW); Trout-Natural (TN); Trout-Put, Grow, and Take (TPGT); and Freshwaters (FW). As of the most recent streams classified, there were no ONRW streams identified, but the Chattooga is a likely candidate. Much of the Chauga and Chattooga Rivers including many tributary waters and Tamassee Creek are currently designated ORW, with special areas designated for TN, and TPGT (SC DHEC, 2001). Any remaining waters are classed as FW. All stream classes have standard restrictions designed to limit water quality effects and protect beneficial uses. In South Carolina, these standards are typically related to water chemistry and toxic pollutants. Suspended sediment has not been evaluated to become a water standard, but turbidity, a surrogate for suspended sediment, is sometimes applied. All classifications include indigenous populations of aquatic organisms as a use to protect and maintain. Water classifications for ORW, TN, and TPGT have special restrictions in addition to FW stipulations to insure protection of the specific resources. The ORW designation applies the antidegradation rule, and trout waters are especially concerned about maintaining adequate dissolved oxygen and cool-to-cold temperatures. In addition, more restrictions are prescribed in recovery plans by the U.S. Fish and Wildlife Service for any waters identified with endangered aquatic species, such as the endangered Carolina heelsplitter *(Lasmigona dicorata)*, a freshwater mussel found in areas of the Stevens Creek subbasin.

Water quality data collected by the U.S.G.S. and State of South Carolina indicate that surface water quality generally meets most of the standards set for uses of streams, rivers, and lakes for general public use and wildlife management. However, many of the streams, especially those within the Enoree Ranger District, are listed by the State of South Carolina as impaired due to elevated fecal coliform levels. Intense storms may produce sediment laden and fecal contaminated waters, especially in the piedmont and below agricultural, pasture, development, and urbanizing areas that are common components to most watersheds. River rafting and water contact sports could be affected by fecal contamination and excessive sedimentation within portions of the Chattooga Wild and Scenic River (Hansen et. al., 1998). Individual stream sections may also be impacted by other specific water quality concerns.

The South Carolina Department of Health and Environmental Control has identified other types of water quality problems for some stream reaches. These problems include some wide ranging, but sporadic, mercury problems across the state as well as some localized pollutants that are associated with point discharges or unknown sources. Copper, zinc, and chromium, likely from industrial or urban sources, affect a few stream sections. Water quality reports that summarize many of these water quality deficiencies are available by subbasin and stream section from the state in subbasin reports and 303d and 305b lists. Where impairments exist, efforts to cooperate with the state to identify, prioritize and formulate Total Mean Daily Loads (TMDLs) to reduce the pollutants to acceptable levels.

Water quality is a concern on the national forest and it has been impacted by past and current activities from various land uses. Current problem stream conditions are summarized below. The approximate percentage of perennial streams identified as impaired by fecal coliform or other pollutants by the state are presented in Table 3-1.

Table 3-1 . Approximate percent of perennial streams impaired with excess fecal coliform or other pollutants by watershed (from SC 303d and 305b lists, 1998)

Watershed number	Watershed surname	Percent of Perennial Streams Impaired
0305010601	Upper Broad	77
0305010602	Turkey Creek (Broad)	95
0305010603	Browns Creek	97
0305010604	Sandy Creek	92
0305010605	Lower Broad River	0.03
0305010607	Little River Broad	0
0305010705	Middle Tyger	96
0305010706	Fairforest Creek	94
0305010707	Lower Tyger River	54
0305010802	Middle Enoree River	97
0305010804	Duncan Creek	98
0305010805	Indian Creek	98
0305010806	Lower Enoree River	98
0305010915	Middle Saluda River	0
0306010102	Whitewater River	0
0306010103	Upper Keowee	0
0306010105	Little River Seneca	0
0306010108	Coneross Creek	98
0306010201	Chattooga River	28
0306010208	Tugaloo River	0
0306010212	Chauga River	0
0306010310	Little Savannah Composite	0
0306010314	Little River - Savannah	0
0306010315	Long Cane Creek	0
0306010603	Lower Savannah	53
0306010701	Upper Stevens Creek	35
0306010702	Turkey Creek	6
0306010704	Lower Stevens Creek	0.12

Primary types of water quality impairment in South Carolina include exceeding standards for fecal coliform and in a few instances, water chemistry as mentioned earlier. Fecal coliform are the indicators of fecal pollution. In themselves, fecal coliform are not specifically hazardous to human health, but they are used to indicate the level of risk or possibility that other more dangerous polluting organisms may be present, such as *Cryptosporidium*, *Giardia*, *Escherichia coli*, *Legionella*, and *Salmonella* species (Scatena, 2000; Stern, 2000; Dissmeyer, 2000).

Inadequate municipal, community, and individual wastewater and sewer collection systems and grazing or other animal uses are a major concern for individual sections of many streams (Zipperer et. al., 2000, Buckhouse, 2000). Wildlife and pets need to be included with potential sources of water contamination. Elevated fecal coliform and other contaminants in stream systems often occur in relation to rainfall-runoff events as pollutants are dislodged and washed into the stream network. When utilized, forested buffers have proven effective in reducing these and other contaminants in streams.

Sediment

Erosion and sediment are major issues in this analysis as many of the activities on the national forest and private lands disturb the land surface, may accelerate soil loss and erosion, deliver sediments to streams, and may affect water quality, riparian, and aquatic habitat. The extent of erosion and sedimentation from roads and forest management and related land use practices have been estimated in the past (Roehl, 1962; Dissmeyer and Stump, 1978; Yoho, 1980; Swift, 1984). Some of these efforts were applied for forest and project level planning and analysis (McLaughlin et. al., 1981, Goddard, 1982 and Hansen et. al., 1994). However, these efforts concentrated more on hillslope and small drainage conditions on the National Forests, rather than addressing watershed scale activities that included private lands within larger hydrologic units. Estimates of sedimentation for land uses were evaluated by watershed in this analysis to consider relative changes from the past and existing conditions, estimate differences in alternatives and to help evaluate the impact on aquatic health which is discussed later in the Aquatic Habitats section (Clingenpeel, 2002, 2003, Scott et. al., 2003; Hansen and Law, 2002). The estimates were based on baseline and existing erosion-based sediment rates at watershed scales and were compared for each alternative. Baseline levels were based on erosion measured by Dissmeyer and Stump (1978) in mature forests by employing the Revised Universal Soil Loss Equation to erosion factors collected for many areas and activities across the Southeastern United States. Existing estimated erosion was calculated in the Region 8 sediment model (Clingenpeel, 2003) for current land use and management activities that occur with each watershed based on soil loss, erosion and sediment coefficients localized to South Carolina rainfall, soil and slope conditions in the mountains and piedmont areas (Hansen and Law, 2002) and the Dissmeyer and Stump (1978) C factor data associated with different activities. The amount of erosion delivered for each watershed used a sediment delivery ratio based on the area of each watershed to determine the amounts delivered Roehl (1962). The details behind the estimates are provided in the process records. Actions designed to prevent or mitigate erosion and improve water quality such as BMPs would likely reduce these values, as the Sumter

National Forest and forestry industry have actively pursued ways to conserve soil and water resources and restore watershed conditions (South Carolina Forestry Commission, 1994, 1999, Hook et. al., 1991, Adams and Hook, 1993, Adams, 1994, 1996, Jones, 2000, McLaughlin et. al., 2002).
Sediment does not have a specific water quality standard in South Carolina that is used to delineate impaired waters in developing the 303d list; however, sediment is used in developing the 305b list where it has direct or indirect impacts on water quality or affects beneficial uses such as aquatic habitats. In a separate study by the Environmental Protection Agency relative to the Chattooga River, tributaries listed in South Carolina as sediment impaired, threatened, or to be watched (monitored) include Whetstone, Long, Fall, King Creeks, and the East Fork of Chattooga River. Turbidity standards are a surrogate to suspended sediment concentrations that may apply in some stream circumstances (SC DHEC, 2002).

Sources of sedimentation vary by watershed, but all ground-disturbing activities contribute to some extent. Agricultural cultivating, grazing, highways, roads, rural, urban and industrial development activities can have substantial impacts. Silvicultural activities that cause erosion and sedimentation include construction and maintenance of permanent and temporary roads, log landings, and skid trails. Since normally only small percentages of the soil surface are exposed in logging activities, non-road or trail related erosion is typically minimal. Only a very small portion of sedimentation can be attributed to landslides and debris flows generated by road construction, skidding, or maintenance and use of roads and trails on colluvial terrain. Much of the sediment input results from eroding road surfaces, slopes, and ditches, particularly those in the proximity of stream channels. A substantial portion of open roads that are bladed, scraped, or otherwise maintained can expose soils and fine aggregate materials to increase erosion and sediment. In addition, similar types of effects come from highways, major collector, and arterial roads that are used for many other reasons where interstate commerce, recreation, occupational, and other human needs for access exist.

In most watersheds, recreational activities are directly or indirectly affecting water quality to some extent. Water can be a critical part in many recreational experiences. Effects of these activities on the Chattooga River will be discussed in another section. Recreational traffic on most of the open road system has a weathering and disturbance impact to the road surface, requiring frequent maintenance of gravel or in some instances, natural road surfaces for safe and efficient access. Off highway vehicles (OHVs),all terrain vehicles (ATVs), and equestrian trails have locally increased stream sediment loads and adversely affected aquatic biota. The intensive OHV, ATV, and horse uses are being mitigated through frequent trail maintenance measures. Off trail or unauthorized uses are often causing problems wherever they are found by compacting, exposing, displacing, and disturbing soils, thereby increasing erosion and sedimentation. Mountain bike and hiking trails can produce erosion and sediment, but their narrow surface and less intense surface impact from normal uses make them easier to maintain and less susceptible to severe erosion.

Activities such as stumping, root raking, debris piling, cultivating, disking, and scarifying related to wildlife openings can expose soils and increase erosion and sedimentation. Since most of these occur on regular cycles, but on relatively flat slopes under 8%, former agricultural lands on river terraces, and on closed road surfaces, erosion and sediment potential are elevated, but generally are not high as long as quality cover is developed and maintained, and mitigation measures are used.

Many streams in South Carolina are impacted by excessive fecal coliform levels. Camping areas, river uses, fishing, and dispersed uses in close proximity to streams, also increase the opportunity for pollution. Without provision for human or other wastes, recreational uses can contribute to pollution and create temporary and intermittent impacts to water quality. User education and commitment to leave-no-trace is important to maintaining the high quality stream experiences.

Chattooga River and River Uses

Much of the Chattooga River affected environment is provided in chapters 3 and 4 of the forest plan in management area and wild and scenic river descriptions. There currently is no flow data or stream gage at any location other than the Highway 76 bridge. Average daily flow records at that station (USGS station number 02177000) are based on average daily flows from October 1939 through September 2001. About one-half of the time, the flow is **524** cfs or greater. Mean daily flow is **648** cfs with a standard deviation of **530** cfs. The lowest average daily flow on record was **88** cfs in October 1954, and the highest daily is **14,800** cfs. The highest instantaneous flow on record was 29,000 cfs on August 30, 1940. Much more detail in flow duration is available, but not summarized here.

The two primary water quality issues identified relative to river uses were fecal coliform and fine sediments. Temperature is a secondary concern within the Chattooga watershed as elevated temperatures affect trout and other aquatic species distribution. From past water sampling and flow records by USGS, State of Georgia, EPA, and USDA Forest Service, Stekoa Creek produces over one-half of the sediment and fecal loading within the Chattooga Watershed. Total maximum daily load (TMDL) for sediment has been set by the EPA for sections of Stekoa Creek, Warwoman Creek, and West Fork Chattooga River (EPA, 2001). Other streams on the 303(d) list in Georgia for excessive sediment, fecal coliform and/or biota within the Chattooga Watershed include portions of Stekoa Creek including tributaries Scotts Creek, Pool Creek, Saddle Branch, She Creek and Chechero Creek, Warwoman Creek, and West Fork Chattooga River including tributaries Law Ground Creek and Roach Mill Creek (GA EPD, 2000). In North Carolina, Norton Mill Creek was included on the 303(d) for sediment due to biological impairment and monitoring will determine the listing and priority of treatment (NC, 2000). The Forest Service cooperates with the states, EPA, Counties, communities and interested publics relative to water quality issues and their resolution with TMDLs, BMPs, restoration or mitigation measures.

<u>Fecal coliform</u> is a water quality indicator of pollution associated with warm-blooded animals, including humans. Fecal material deposited on the landscape may get into

solution during storm events and may move to streams if not absorbed within filter strips, and filtered through soil. The fecal coliform levels within the Chattooga River and tributaries found during storm events are often high enough to be of concern to swimmers and to other water contact sports that are often present when floating the river. This is especially true of storms that are intense or that follow dry periods. The water quality in Stekoa Creek suggests that even non-storm periods are intermittently or perhaps even regularly contaminated by fecal materials (USGS stream data, Hansen et. al., 1998).

The actual extent of contamination by the individual potential sources has not been fully documented, but water quality tests conducted by the USGS show intermittent problems during storm events and added frequency and severity associated with large loads from Stekoa Creek and, to a lesser extent, other sources. The RNA methods are available to verify the types of contamination among human, cattle, geese, beaver, wildlife, and other sources. These tests would involve analyzing specific coliform levels in water samples to differentiate RNA indicators found from different fecal sources. The contamination of fecal material from the river use is difficult to estimate. It should be noted that during the warm periods with moderate flow levels, the equivalent of 5-10% of the Chattooga watershed human population is floating the river, increasing the potential for human waste materials within the river corridor. Probably many river visitors use existing waste disposal facilities. However, signs of disposal of human waste within the dry portions of the stream channel, as well as within the floodplain or terrace, are sometimes evident. Some of the fecal material will find its way into the Chattooga River system. Fecal coliform increases are well documented in association with storm events both in the Chattooga River and in streams that do not have the rafting uses. Without further study, the level of fecal contamination from the river or any other uses cannot be determined. Hansen et. al., 1998, discuss a summary of fecal problems and a variety of information sources relative to the Chattooga River, highlighting the past and ongoing severe fecal contamination associated with Stekoa Creek.

Other recent USGS information collected in 1997 provides more intensive fecal coliform sampling within the Chattooga River and major tributaries (figure provided previously). Unfortunately, only a few samples were taken associated with storms. Individual samples were taken in the Chattooga River at Highway 76, Stekoa Creek, Warwoman Creek, West Fork Chattooga River, and North Fork Chattooga River. Maximum values reported for these streams included 490; 54,000; 7,900; 3,300; and 230 MPN fecal coliform/100 ml, respectively. Except for the North Fork of the Chattooga River, all major tributaries were substantially greater than the allowed water quality standard for swimming that is set at 200 MPN/100 ml, with infrequent variances to 400 MPN/100 ml. All of the above readings except for the North Fork locations were taken during the June 12, 1997 storm under moderate flow conditions. During that day, the measured flow at the Highway 76 stream gaging station was 929 cubic feet per second (cfs). Further verification from the past data records shows elevated fecal contaminants, especially during storms in some of the tributaries are not uncommon, suggesting excursions above water quality standards are not unusual.

The direction in the 1985 forest plan relative to the concern over fecal coliform (on page M-9) has been only partially implemented. However, some improvements in waste facilities have been provided since 1985. The primary fecal contamination issue is from a health and safety standpoint associated with water contact sports such as swimming. A monitoring plan is needed to determine the effects of the activity on water quality and to identify the sources of pollutants for possible treatment or improvement. Those that float the river should be informed of the risks involved with swimming during and following storm events and also in swimming within problem reaches such as the river section below the confluence with Stekoa Creek.

<u>Sediment</u> - Mobile fine sediments of sand size and finer particles were sampled within the Chattooga Watershed (Van Lear et. al., 1995). They were composed primarily of medium to coarse sands (70-90 percent), followed by very coarse sands (5-25 percent) with very fine sediments (i.e., fine to very fine sands, silt and clay, 1-5 percent). Between Bull Pen and Dick Creek, 63 to 85 percent of the pool area were impacted by sands. Fine sediments are extremely impactive to fishery and aquatic habitats (Reiser and White, 1988, Platts et. al., 1989, Durniak and Rudell, 1990). Erosion and sediment levels are normally high, to some extent due to the high rainfall, well-weathered soils, and steep and dissected slopes. Historic timber harvest, roads, skid roads adjacent or within stream channels, splash dams, farming, mining and other practices add to the current legacy sediment sources that contribute to the high sediment levels within the Chattooga River and many tributaries (Alger, 1994).

The banks of the river are entrenched and steep, with bank erosion problematic in some locations due to past or current disturbance. However, most areas are stable, with forested slopes dominant and narrow floodplains built over time. Substantial portions of higher gradient channel areas are dominated with bedrock, boulder and cobble materials. Lower gradient sections, pools, glides, point and side bars have gravel components with a dominating trend of light to heavy sand deposits adhering to mossy growth and covering areas of slack water including stream margins and floodprone areas. Recreational impacts include road and trail crossings and sometimes paralleling stream channels, banks, and campgrounds and parking areas in the immediate vicinity. Recreational activities may expose soils and/or dislodge fine particles from the streambank and streambed. River users may stir-up some fine sediment in the margins of the channel as they get in and out of rafts, which can contribute to localized turbidity and sediment levels. This disturbance is most noticeable during lower flow levels, and generally quickly dissipates in most cases, as the particles move downstream to redeposit on the margins or in pool areas. Large particles suspended for short durations during storm events are often termed "bed load." Finer particles are suspended for extended periods during and following storms events, and are most commonly referred to as suspended sediment. Sediments that are smaller in size than medium sands have impacts to a variety of aquatic species (Braatz, 1993). These sands are mobile, abrasive to algae and other organisms, and can clog and limit benthic flow properties that are needed for the health of some organisms.

Van Lear et. al., 1995, reported only small portions of the total suspended solids in tributaries were made up of fine sand and smaller materials. However, the sediment levels within Stekoa Creek are of special concern because the magnitudes overwhelm the lower channel with sediments, producing over half of the Chattooga watershed sediment load (USGS data, Hansen, 1993). Visible turbidity and sediment accumulations are evident, especially during and immediately after storms. Sediment plumes and excessive sediment cover the channel and marked accumulation on all depositional features including pointbars, sidebars, and flood-prone areas.

Temperature is a concern relative to the river and related to the extent of trout habitat and other aquatic species. Temperature was not included as an issue of the river uses since the likelihood of a cause and effect relationship is low. Most of the temperature increases are natural for a wide shallow channel. Although there are few ponds on tributaries within the watershed, some have been retrofitted for bottom releases to reduce the effects in the summer months.

Riparian resources: Wider portions of the floodplain and terraces that are accessible are sought out by river floaters and used for picnics and camping. Except for the river access points that must cross riparian areas, these camping and picnic areas are the most likely to be impacted by river users. Impacts include soil exposure, damage to riparian vegetation from compaction, and sometimes, soil erosion. Some of the formerly farmed bottomland river terraces continue to be used for wildlife openings and maintained in early successional habitats. These generally are on low gradient slopes and offer low to moderate risk for sediment. Where these infringe into the primary streamside management zone, concerns besides sedimentation may include stream temperature, solar effects on stream vegetation, large woody debris recruitment, herbicides, pesticides, and bank stability are evaluated.

There are floodplain areas contained within the extent of riparian areas, but probably few if any wetlands. Most, if not all, of the riparian areas are well drained alluvial deposits and develop riparian, but do not develop wetland soil and plant communities. None of the activities being used or proposed would likely damage floodplains, but some elements of EO 11988 may be appropriate to consider if facilities are located within the floodplain. Protection of river users and property is needed by signing floodplain hazards at known use areas and by displaying flood hazard zone in river maps or other informational materials on public camping sites, parking areas, designated river access, or recreational use facilities.

Some riparian vegetation and soil impacts are possible from concentrated uses, such as access. These uses can generally be limited in extent and impact through quality design and location, regular monitoring, maintenance, and mitigation.

Potential Creek Floating Use above Highway 28: Water quality and stream information for the North Fork Chattooga subwatershed was summarized by Hansen (1998). The Grimshaws Road 1107 crossing (NC) has a drainage size of 7.98 square miles and Highway 28 crossing (GA/SC) has 66.4 square miles (Hansen, 1998). These are 4% and 32% of the drainage area of the stream gage at Highway 76. Since there are no stream gages at the potential put-in points, one can roughly estimate the flow by taking these percentages times the Chattooga at 76 site. This may give a conservative estimate, as more rainfall and runoff may occur in the headwaters. Based on the Chattooga flow duration curve for duration of 0.05 (about 18 days per year) and 0.1 (about 36 days per year) percent chance of flow exceedance, Grimshaws flows 50 and 38 cubic feet per second (cfs), respectively. The North Fork at its mouth flows about 500 and 380 cfs for those durations. In other words, about one month each year the average flow is above 50 at Grimshaws and 500 cfs at Highway 28.

Other potential access points between Grimshaws and Highway 28 include Bull Pen Road 1178 (NC), Burrells Ford Road 708 (GA/SC), and possibly hiking the trail from the end of Big Bend Road 709 (SC). Foot traffic has access along much of the river with Bartam and Chattooga River trail, Chattooga Foothills trail, and Ellicott Rock trail. The North Fork Chattooga subwatershed is about 97% in forest land uses with about 1% each in exposed soil or rock, pastures, and forest edge/shrub. Elevations range from 1,576 to 4,902 feet, with the Grimshaws Road 1107 access at approximately 2,800 feet, Bull Pen Road at 2,400 feet, Burrells Ford Road at 2,000 feet, and Russell Bridge (Highway 28) at 1,600 feet. Numerous water monitoring site stream data are available for various tributary drainages in this section of river. The North Fork channel at Highway 28 is described as a Rosgen F3 channel from the entrenched cross section with moderately high width-to-depth ratio measurements. Some obvious sand sediments (40%) were documented in the riffle/run section measured for particle size distribution. Low bank erosion and scouring were noted at the site. The subwatershed was listed in South Carolina Salkehatchie-Savannah Water Quality Management Strategy (SC DHEC, 1993) as an unimpaired water with notable trend in fecal coliform and turbidity with poultry farms and silviculture listed as potential causes and is being studied for NPS-BMPs for waste reduction and further evaluation on the turbidity concerns. Current impaired 303(d) lists have delisted some sites as they refine the process to identify and verify waters with major problems. Several of the drainages contributing to this site were sampled in the Van Lear study. Many tributary Chattooga sites sampled had relatively good water quality with generally low to slightly elevated storm total suspended sediment concentrations as compared to Stekoa Creek, Big Creek (West Fork Chattooga) and Whetstone Creek that had much higher total suspended solids during storm events. North Fork Chattooga River benthic macroinvertebrates were sampled in conjunction with the Chattooga Demo and rated excellent with a NC biotic index of 3.03 for qualitative samples (Weber and Isley, 1995). Sampling aquatic macroinvertebrates in 1986 (site C9) indicated a very good rating using diversity indices (English, 1987).

North Fork fecal coliform data that are available indicate likely past problems with contamination in the subwatershed in the late 1960s and early 1970s at the Grimshaws and Bull Pen sampling locations (Hansen, 1997). Fecal colifom levels in the thousands had apparently diluted to hundreds by Burrells Ford with some rebound in numbers below the West Fork. Limited data in the 1970s and 1980s suggest that the problem activities have been taken care of or they are intermittent and difficult to sample.

Chattooga River at Grimshaws (NC) has a drainage area of less than 8 square miles. The land use is dominated by forests (92%) with 3% bare or developed, 1% pasture, and 2%

shrub/edge, and includes about 27 miles of road. Sampling aquatic macroinvertebrates in 1986 indicated very good rating using diversity indices (English, 1987). Fecal coliform data available indicated some likely past problems. The location is the upper boundary of the Chattooga Wild and Scenic River Corridor. The Chattooga at Grimshaws was rated as a Rosgen F1a channel (Hansen, 1998). The entrenched, high width-to-depth ratio channel is bedrock dominated and was affected by fine sediments in both pool and riffle sections. Please refer to Appendix H for a further discussion and analysis of this issue.

Direct/Indirect Effects

Water Quality

Hem (1960) provides an excellent review of the chemical aspects of water quality. Slight changes in water chemistry may occur relative to forest management, but the research shows that these typically are minor or short lived. Some pollutants from vehicles may eventually make their way into the water column with storm events or wash off when streams are forded. Although once an issue before streamside management zones were instituted, stream temperature effects for most activities are negligible. Fecal coliform effects can emerge where concentration of people, animals, or wildlife occur. Turbidity and sediment continue to be major effects on water quality as many forest management activities contribute to these.

The effects of erosion and sediment are a major part of the forest plan analysis, Issue 4 on Riparian Area Management, Water Quality, and Aquatic Habitats. Delivery of erosion to streams is referred to as the sediment delivery ratio as quantified by Roehl (1962) in the inverse relationship between sediment delivery and hydrologic unit size. Sediment delivery of erosion into intermittent and smaller streams with drainage areas of 5-50 acres is within the 50 to 70% range, and about 35% for small perennial streams with areas of about 200- 400 acres (Roehl, 1962; McLaughlin et. al., 1981; Hansen, 2000). For watershed scale areas of 40,000 to 250,000 acres, Roehl's average sediment delivery ratio reduces to 11 and 6%, respectively. However, substantial variance exists in Roehl's data, as well as some differences between physiographic areas that should be noted.

The highest sediment rates occur during the larger rainfall events. However, it is typically the storms with an average frequency of about 1.5 years, often referred to as bankfull flow, that actually define channel morphology (Rosgen, 1994). Over time, these less severe, but frequent events probably move the most sediment. Less frequent floods such as a 100 year event may have higher sediment loads, but the bankfull flow occurs nearly every year and sometimes more than once in a single year, enabling it to move higher quantities of sediment with time. Bankfull flow also keeps the channel scoured and relatively free of perennial vegetation in most circumstances.

Much of the sediment deposited in stream channels originates between what is delivered to headwater streams and what remains in suspension at the watershed boundary and is used to form point bars or may be deposited in the channel or onto floodplains. Sediment management is a natural, ongoing process in streams. Streams in balance with their sediment loads manage to process and sort the materials, building and renewing habitats, depositing the finer particles on the stream margins, in pools, and in floodplains. However, if too much sediment is delivered, the system can become overloaded, resulting in changes in habitat, channel capacity, channel morphology, and flooding. Excessive sediment begins by causing active channel deposits that can fill pools, converting them to runs, and reducing aquatic habitats. When deposits are overwhelming, channels adjust by aggrading, initially developing side and internal bars and eventually changing form. Continued excess sedimentation develops to a braided condition from sediment accumulation and loss of sediment moving forces due to more frequent out of bank flows. Many of the functions and habitats are lost under the braided stream circumstance (Rosgen stream type D). Braided streams are infrequent on the Sumter National Forest, but localized sections are sometimes found where moderate to steep gradient channels with high sediment loads meet low gradient valley conditions. During the active gully formation period, many valleys may have developed this braided stream character because the supply of sediments so greatly exceeded the streams ability to carry it (Happ, 1945, Rosgen, 1996). In most instances, once the supply of sediments subsides, the stream will begin the process of reversing this trend with the entrenchment and widening processes discussed earlier.

Water Quality Effects from Activities

Like soils, ground-disturbing activities may produce effects to water quality. A portion of the erosion effects in the soil section reach streams and can have an influence on water quality and aquatic habitats in the form of sediment. Major areas of activity that disturb the ground and produce sediments include: 1) roads and trails, 2) vegetation management, 3) fire management, 4) wildlife management, 5) recreation management, and 6) soil and water improvements. Other management areas have activities of lesser extent such as mining, utility corridors, dams, river use, and other special uses that can influence water quality. As mentioned, many of these effects can be avoided, minimized, and mitigated.

Direct effects to water quality typically are related to road, trail, dam, dike, fish structure, debris installation or removal ,and other types of ground disturbing or heavy equipment construction that occurs within or immediately adjacent to streams. Most of these direct effects are avoided when possible or minimized in BMPs, forest standards and implementation guides (McLaughlin et. al., 2002). Where appropriate, necessary permits are obtained to operate within navigable streams, active channels, floodplains, and connected waters. Adjustments to plans ensure consideration of avoidance, minimization, and mitigation alternatives or actions. In addition, adherence to any state and federal permits or direction that regulate activities and sediment controls are required. Mining, utility corridors, construction, recreation, and river use can produce erosion, sedimentation, and/or channel changes that are addressed in detailed activity plans.

Indirect effects to water quality from activities are typically a result of rainfall and runoff sequences that deliver soil particles and other pollutants to streams. Pollutants come from a variety of sources including vehicles, people, pets, animals and equipment as they cross streams, expose soils, and change the surface vegetation cover, soil, or hydrologic functions. These non-point sources of pollution are dispersed with time and location, and may not enter streams unless specific events or conditions occur. Pollution from roads, trails and recreation has been discussed in other sections. Dams and dikes alter surface hydrology and need regular attention to maintain the structure. Without regular maintenance, weakening and eventual failure could result, as well as added effects to water quality and downstream areas. Water quality effects vary with the structure and location, but include changes in dissolved oxygen, aquatic organisms, chemical and sediment balance (Glasser, 2000). In addition, water birds and some terrestrial species affect the biological, nutrient, and chemical quality of water (Nadareski, 2000). Care in designing projects to protect from failure during flood events, such as limit return flows and manage pollutant release are helpful.

Stream chemistry effects from forest management practices are typically minor and temporary, but can be affected by activities such as vegetation harvest, vegetation conversions, prescribed burning, fertilization, and pesticide applications (Stednick, 2000; Landsberg and Tiedemann, 2000). In all of the alternatives, stream buffering designed to protect water quality from most forest management is included with SMZs and forest standards in Alternative F; and with SMZs, the riparian corridor prescription and forest standards in the other alternatives. Activities within the riparian corridor will consider effects to aquatic systems, avoiding or minimizing effects where possible.

Erosion can be a good indicator of water quality change from activities, recognizing that erosion reaching streams varies with the width and effectiveness of stream buffers (Swift, 1988). Delivery of erosion varies by position on the landscape, with the locations closest to hillslope processes getting the highest delivery rations. In small intermittent and scoured ephemeral streams, delivery may be 50 to 70%, with about 35% delivered into small perennial streams and below 10% at watershed scales (Roehl, 1962). In addition, average annual water yield from the national forest is over 1 billion tons of water that aids in the suspension, dilution, transport and deposition of most of the sediment (Hansen et. al., 1994). Preventative or mitigative measures such as BMPs, standards and guidelines can be very effective at limiting the delivery of sediments into streams.

Water Quality Effects by Alternative

Erosion delivery as sediment is the major factor that can contribute to water quality and habitat decline, but it is certainly not the only element of water quality. Some pollutants adhere to soil particles in the erosion and sediment delivery processes. Other pollutants may be altered in some way due to the presence or absence of sediments. However, total erosion estimates are probably one of the best indicators of overall water quality change to be expected on the forest in evaluating each of the alternatives. Based on the total erosion estimates for probable activities by alternative, Alternative G has the least erosion from national forest management activities with 30,100 tons/year. Alternative D had 49,000 tons/year; B, 50,800 tons/year; I, 51,600 tons/year; A, 53,800 tons/year; E, 57,200 tons/year, and F, 58,700 tons/year over the first decade. Addressed with other units and spread over the national forest, these values range from 53-to-103 tons/square mile/year (see Figure 3-1), which is equivalent to 0.08-to-0.16 tons/acre/year.

Assuming a sediment delivery ratio of 0.34 in headwater perennial streams, the average concentration increase among the alternatives based on approximately 1.03 billion tons of water yield produced on the Sumter National Forest each year would be 10 parts per million (ppm) in alternative G to 19 ppm in alternative F. At watershed scales with the average sediment delivery ratio of 0.07, the mean concentration change would range from 2 to 4 ppm. In the proposed alternative I, average impacts to headwater perennial streams would be increased sediment of 17 ppm and to watershed scales the mean concentration increase would be 3.5 ppm. So compared to fully implementing the 1985 plan (Alternative F - Current), the proposed action would produce a small reduction in sediment effects from the current alternative.

Water Quantity

Most water quantity or water yield changes in streams during the next planning cycle will be related to the road, vegetation, and habitat management. Water yield in streams typically increases permanently from road building and conversion from forests to grasslands. Temporarily, increases in flow may follow after timber harvesting or vegetation removal practices. Since pine forests produce more water than hardwood species, there are some increases in water yield as forests are converted to hardwood species. The following sections discuss some of the background information associated with water quantity increases from activities.

Roads and Trails

Substantial change in water yield may result from cutting and filling slopes to make a road or trail surface. Soil compaction of roads, log landings, trails, and other compacted surfaces impede infiltration and increase runoff. Most quick flow water increases from National Forest System lands are probably from roads. Compacted road surfaces probably contribute nearly 80-90% of the rainfall as water yield, much of which would be stormflow. Small or light rainfall events could have substantial surface absorption and evaporation, but large or intense events develop runoff. As water moves to the shoulder and into ditches and filter zones, much of it can be absorbed into filter strips if frequent drainage features are utilized as recommended in BMPs. Roads surfaces are typically only a small portion of large areas, so at large drainage to watershed scales, their effect on water yield is muted. At project or localized scales, roads can have a substantial effect on capturing and channeling excess rainfall, surface runoff, and, in some circumstances, subsurface flow along their path. Additions of road stormflow to local intermittent or ephemeral streams produces minor to substantial effects. A road across and draining into some small streams may not be just a small portion of the drainage area. With their ability to capture surface and subsurface flow along with providing substantial stormflow from their surfaces, roads can easily overload small drainages with excessive flow. These localized effects are most noticeable when the drainage structures in roads are not frequent enough or in terrain where the channels have entrenched into saprolite or other unconsolidated materials. These effects are substantially reduced by strictly following BMPs, which utilize frequent water diversions of surface flows into the forested buffer zones, to dissipate much of the storm water effects that contribute to quickflow and these off-site effects. At the project level, road density and location can have extraordinary effects that will be evaluated at that level.

Vegetation Management

The temporary effects of removing vegetation or permanent conversion of vegetation types that intercept and transpire rainfall can influence water yield. Different types of vegetation have different rooting, stomata, leaf or needle coverings, and growth habits that can affect the amount of water utilized in evapotranspiration processes. In general, grass cover yields more flow than forests, and hardwood forests yield more than pine forests. So areas converted from forests to woodland, savanna, or wildlife openings will likely provide some permanent increases in flow. Timber harvest temporarily removes vegetation that transpires a substantial amount of water each year. The most notable changes in water yield from timber harvest is usually augmentation of summer low flows (Swank et.al., 1989), with lesser effects to peak stormflows. Much depends on soil and site conditions, storm intensity and duration, as well as antecedent soil moisture conditions (Lull and Sopper, 1965; Anderson et.al., 1976). The amount and duration of this increase also depends on the percentage of basal area (BA) removed as well as forest type. As mentioned earlier, road and other compacted surfaces can increase stormflow, but whether it shows up more as quickflow or delayed flows depends, in part, on the level of BMP implementation. Timber harvesting in pine generates a greater increase in total water yield than hardwoods or mixed pine-hardwood types. Return to preharvest water yields is typically within 10 years, as regrowth is rapid. Swank et al, 2000, noted that there was extra water use in fast growing stands about age 15-18, which might show up at a slightly younger age in fast growing areas of the piedmont. During this time, healthy pine stands are growing their fastest. The recovery of water yield enhancements from harvests will be quicker for partial cuts or thinnings, where trees are ready to take up and utilize much of the residual water. Harvesting in hardwood or mixed stands may produce many sprouts that rapidly grow and continue to transpire, dampening or shortening the water yield increases common to pine regeneration. In all alternatives, vegetation manipulation will include a combination of seed tree, shelterwood, thinning and partial cuts such as group selection or patch cuts. There will also be an effort to restore woodland and savanna habitats that will require thinning areas to about 40 sq. ft. basal area per acre for woodlands and 10-20 sq. ft. basal area for savannas. Prescribed burning will be used at frequent intervals on those areas to obtain native grass understories. In sloping terrain or areas with shallow surface soils, duff and/or humus, added measures such as sowing or planting native grass or other species may be needed to insure timely recovery of the site and conversion to suitable species.

When the water yield changes from the road network, parking areas, timber harvesting, woodlands, savannas, openings, and SPB are taken into account, both short term fluctuations and long term water increases are expected in both stormflow and baseflow.

These increases are more associated with concentrated areas of activity, and more difficult to discern at watershed or landscape scales. The increase in surface storm runoff may cause some localized soil movement, streambank cutting, ephemeral channel scouring, and possibly, stream sedimentation. Increases associated primarily with transpiration reduction may also augment low flows that are so critical for aquatic habitat.

Water Quantity Effects from Activities

As mentioned, compacted road surfaces probably contribute nearly 80-90% of the rainfall as water yield, much of which would be stormflow. These changes are more or less permanent and often increase quickflow rather than baseflow. Compacted surface flow impacts can be mitigated to some extent where frequent cross drainage is used to increase infiltration and reduce channelized flow, erosion, and sediment delivery to streams. Vegetation removal can increase flow up to 40%, returning to original levels over a decade, with vegetation conversion from forest to grassland a lesser, but continuing, effect is likely. Since much of the harvest activity involves thinning or partial harvesting, effects would be much-less-to-negligible on those areas.

Based on local knowledge and field observations, stream channels within the mountains and larger stream channels on the piedmont are usually capable of handling the small increases in flow that are projected for each alternative without causing excessive channel erosion. Small intermittent and ephemeral streams, especially those with entrenched channels with unconsolidated or erosive bank materials, and in severely eroded terrain, can be affected if activities concentrate within these drainages or when BMPs are not fully utilized to limit direct additions of surface flow to headwater streams and gully systems. Short-term increases in water yield during summer low-flow periods associated with most types of timber harvesting is almost always a benefit in downstream aquatic habitats and is also an indicator of higher water tables for increased riparian vegetation and aquatic health along perennial, intermittent, and some ephemeral streams. At project level analyses, high densityof roads, road capture of flow, road surface drainage, timber harvest, conversion of forests to non-forests, restoration, and other activities may need further evaluation for potential water quantity and quality effects on vicinity stream channels. Spacing activities through time and applying BMPs are the best ways to help reduce effects.

Water yield changes can have some direct and indirect effects on resources and water supplies. Currently, water supply vastly exceeds use in most areas of South Carolina. In a few locations, however, use has risen to consume a substantial portion of the supply, especially during low flow or drought conditions. Future water demand is expected to follow population growth.

Water Quantity Effects by Alternative

The indirect effects of the changes in water yield for each alternative were estimated. Baseline water yield for the Sumter National Forest was estimated at approximately 25